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Program Manual for Estimating Use and Related Statistics on Developed Recreation Sites

by

Gary L. Tyre
and
Gene R. Welch

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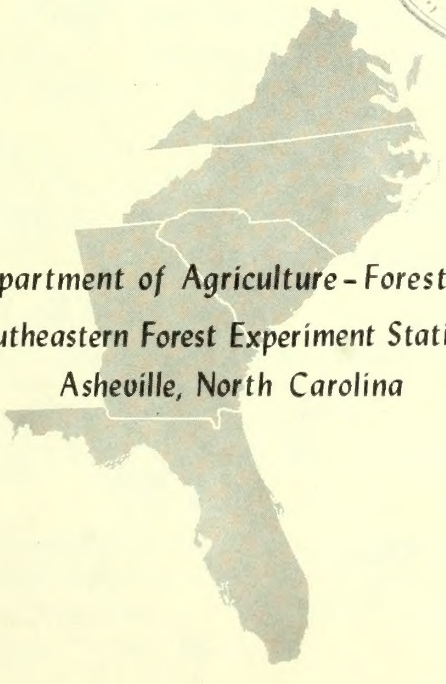

U.S. Department of Agriculture - Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

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Program Manual for Estimating Use and Related Statistics on Developed Recreation Sites

by

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and

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Introduction

Use and use-related information is essential to the planning, management, and operation of developed recreation sites. This information is needed to establish schedules for visitor information programs and trash disposal and to determine access requirements and maintenance needs. Estimates of use have immediate utility in identifying trends and patterns which are important in determining what activity demands are and what facilities will be required to support them. Also, consistently high use estimates may warn of dangerous peak loads having severe and irreversible biological impacts which may require immediate attention.

While the immediate utility of good use information is important, its greatest significance lies in formulating long-range planning and management goals. For instance, consistently estimating use below design capacity may indicate faulty design assumptions and could possibly show that better information is needed in locating developed sites, that the mix of facilities might be improved, or that development toward a different experience level should be considered. Use information is helpful in predicting depreciation rates of both facilities and the natural environment. Use data, if reliable and widespread, will permit systematic area planning rather than piecemeal planning of individual places, and they can form the basis of long-term budget preparation.

Recognizing the essential nature of such information, researchers have developed a wide and successful variety of techniques for developing use estimates and associated measures of error for developed sites (1, 9, 10) and for widely dispersed areas (2, 4, 5).

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One of the more popular techniques has been described by James (3) and has been applied on more than 800 developed sites within National Forest lands. Much of the popularity of this technique stems from its use in the USDA Forest Service's Recreation Information Management (RIM) program (7)--a computer-oriented approach to the accumulation, storage, retrieval, and display of information about people, places, and things (8). Part of the emphasis in RIM has been directed toward a broad sampling effort designed to introduce a large segment of managers to statistically founded approaches for use estimation.

The essence of this technique is simple linear regression whereby counts of people entering, people engaging in a variety of activities, and equipment in use serve as dependent variables and are regressed against metered counts from traffic counters or water meters (6) and which serve as the independent variable. The data from which the regression equations result are generated from a random selection of sample days. The recommended number of 12 sample days has usually proved sufficient for developing equations which yield season-long estimates well within a precision level of ±25 percent at the 67-percent level of probability.

For each of these 12 sample days, an observer is required on the site at 0900 (military time) to record the initial meter reading for that day. Following this, the observer stands at the site entrance from 0900 to 0915 and records the number of people entering the site during this interval. After this visit count is made, the observer travels through the site making a count of the number of people and recording the activity in which they are engaged. This procedure is followed for 12 hours on each sample day so that the last observations are made during the interval from 2000 to 2100. For each of these 12 sampling rounds, this approach attributes 1 hour of recreation use to each person engaged in recreation activity and estimates hourly visits by multiplying by 4 the observations in each 15-minute visitor-count interval. During the late afternoon and evening rounds, the observer tallies the number of people using each facility grouping so he can estimate the number of people expected to use the site overnight. Twelve hours of recreation use is attributed to each overnight user. The observer's last task is to return to the site at 0900 on the morning following the sample day to record the metered count. The difference between this reading and the reading recorded at the beginning of the sample day provides a value for the independent variable, and the sums of the hourly observations for visits and use by activity provide values for the dependent variables.

This procedure can be effectively applied on single sites or on two or more contiguous sites (called complexes) that lend themselves to common sampling. Also, it can be used on most developed sites where the independent variable can be completely metered over the period for which estimates are desired. Generally, estimates are developed for that part of the year when the greatest use is expected, usually from late spring until Labor Day. Estimates can be generated for an entire year, but stratification of the year into high- and low-use seasons usually results because of the excessive variability in use on most sites.

The technique has been encouraged in RIM because it has the flexibility for application on a variety of developed sites and because it could easily be extended to provide other information, such as visitor origin, occupancy rates, and daily-use patterns. Its increased application has fostered interest not only within the Forest Service but among outside parties as well. The growing interest in this technique has been accompanied by a corresponding increase in requests for programing and documentation. This manual is intended to meet these demands and should be used in conjunction with an earlier publication on the technique (3). Most of the programs and documentations presented here have been expanded and generalized from materials developed at the RIM Data Processing Center, Forestry Sciences Laboratory, Athens, Ga. These programs are naturally oriented toward application within the administrative framework of the National Forest system, but key points in all programs are indicated so they can be easily modified to fit any organization's needs.

Program USEST is designed to give season-long estimates and error terms for visits (actually an estimate of entries and not truly a visit estimate), visitor-days of use[1] for each of 12 activities, total visitor-days of use, and amounts of overnight equipment in use by type, i. e., auto, tent, or trailer. Program POC provides an analysis of the rates of occupancy of sampled picnic grounds and campgrounds. Program USPAT is designed to provide managers with a better idea of the pattern of use exhibited by sampled sites. Program ORGIN develops indicators of visitor origin and enables managers to become more familar with the clientele with which they are dealing.

These programs are all written in the Fortran IV compiler source language. They were developed for execution on IBM 7094 hardware and are operational for that system in IBSYS version 13.[2] They can be easily adapted to any other system having a Fortran IV compiler.

Data Handling and Management

The nature of input data necessitates general comment relating to these programs. Exhibit 1 shows the sampling record which summarizes field information gathered daily; it indicates that 25 cards are required if entries are recorded in all fields (see Appendix 5a for format of input). Experience has indicated, however, that only in rare cases will all fields be filled, and the RIM Center has not required that cards be punched unless to record field entries.

---

[1] Recreation use which aggregates 12 person-hours. It may involve one person for 12 hours, 12 persons for 1 hour, or any equivalent combination of group use, continuing or intermittent.

[2] Use of trade, firm, or corporation names is for the information and convenience of the reader and does not constitute endorsement or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Exhibit 1

CARD 1

USDA-FOREST SERVICE **SAMPLING RECORD** **DEVELOPED RECREATION SITES** (DOUBLE SAMPLE TECHNIQUE) *(Ref: FSH 2311.71)* **PART I - DAILY SUMMARY**	A. card no. (1-2) 01	B. region no. (3-4)	C. forest no. (5-6)
	D. dist. no. (7-8)	E. principal site no. (9-12) kind (13-15)	
	F. set no. (16-17)	G. principal site name (18-58)	

TRAFFIC/WATER METER READINGS	STATION 1	STATION 2	STATION 3	STATION 4
0900 HOURS ON SAMPLE DAY				
0900 HOURS ON NEXT DAY				
24 HOUR DIFFERENCE	(59-63)	(64-68)	(69-73)	(74-78)

CARDS 2-13

TIME OF DAY	VISITS	NO. OF PERSONS ENGAGED IN COMPONENT ACTIVITIES											
	tallied 15 min. hr. at 1 entrance	43.1	41.1	21.0	22.1	22.2 & .3	boat launch		1.3	visitor service		1.1	other specify activity (74-76)
		picnicking	camping (gen.)	team sports	swimming bathing	water sports	12.0 power	15.0 non-power	spectator sports	81.1 &.2 exhibits talks	81.3 &.4 tours	view scenery	code
	(18-22)	(23-27)	(28-32)	(33-37)	(38-41)	(42-45)	(46-49)	(50-53)	(54-57)	(58-61)	(62-65)	(66-69)	(70-73)
0900													
0915	→												
1000													
1015	→												
1100													
1115	→												
1200													
1215	→												
1300													
1315	→												
1400													
1415	→												
1500													
1515	→												
1600													
1615	→												
1700													
1715	→												
1800													
1815	→												
1900													
1915	→												
2000													
2015	→												

CARD 14

TIME OF DAY	FACILITY GROUPINGS BY PERCENT OF DESIGNED/CONST. CAPACITY UTILIZED						
	NO. OF FACILITY GROUPINGS						
	AT OR BELOW LOWER LIMIT				ABOVE UPPER LIMIT		
	vacant	"gear" only	below lower limit	within limits	less than 25% above	25% to 75% above	more than 75% above
1215	(18-20)	(21-23)	(24-26)	(27-29)	(30-32)	(33-35)	(36-38)
1815	(39-41)	(42-44)	(45-47)	(48-50)	(51-53)	(54-56)	(57-59)

OVERNIGHT USE (Post from 2015 round and/or supplemental information			
NUMBER OF OVERNIGHT CAMPERS	TYPES OF OVERNIGHT EQUIPMENT IN USE (no. of)		
A. persons (60-64)	B. auto (65-67)	C. tent (68-70)	D. trailer (71-73)
E. observer	F. date of sample → month (74-75) day (76-77) yr. (78-79)		

2300-40 (11-70)

HIS: 80, 5E-2

Exhibit 1 (continued)

PART II **VEHICLES BY STATE OF ORIGIN**	INSTRUCTIONS: Complete for each sample day. Tally vehicles on-site during the 1215 & 1815 rounds.

CARDS 15-24

STATE OF ORIGIN

STATE NO. (18-19)	STATE NAME	NO. OF VEHICLES ON SITE 1215 HOURS (20-23)	NO. OF VEHICLES ON SITE 1815 HOURS (24-27)	STATE NO. (18-19)	STATE NAME	NO. OF VEHICLES ON SITE 1215 HOURS (20-23)	NO. OF VEHICLES ON SITE 1815 HOURS (24-27)
1	AL			31	NB		
2	AK			32	NV		
[illegible]	AZ			33	NH		
5	AR			34	NJ		
6	CA			35	NM		
[illegible]	CO			36	NY		
9	CT			37	NC		
10	DE			38	ND		
11	DC			39	OH		
12	FL			40	OK		
13	GA			41	OR		
15	HI			42	PA		
16	ID			44	RI		
17	IL			45	SC		
18	IN			46	SD		
19	IA			47	TN		
20	KS			48	TX		
21	KY			49	UT		
22	LA			50	VT		
23	ME			51	VA		
24	MD			53	WA		
25	MA			54	WV		
26	MI			55	WI		
27	MN			56	WY		
28	MS			72	PR		
29	MO			99	UNDIFF.		
30	MT						

CARD 25

PART III **SEASONAL SUMMARY OF PERTINENT INFORMATION**	INSTRUCTIONS: Complete only once for the sampling season. Entries not required for block C unless more than one site is included in the sample.	A. set no. (16-17) 99

B. SAMPLING TECH. (1.1 for single sites - 1.2 for site complexes) (18-19) __

C. OTHER SITES INCLUDED IF A SAMPLING COMPLEX

no. (20-23) ___	kind (24-26) __	no. (27-30) ___	kind (31-33) __	no. (34-37) ___	kind (38-40) __	no. (41-44) ___	kind (45-47) __

D. SEASON CALIBRATED

calibration season began (48-49) mo. __	(50-51) day __	(52-53) yr. __	calibration season end (54-55) mo. __	(56-57) day __	(58-59) yr. __	total days in season (60-62) ___

E. TOTAL NUMBER OF FACILITY GROUPINGS (63-65) ___

F. TOTAL NO. OF SITE ENTRANCE ROADS (66) _

G. TOTAL SEASONAL METERED COUNT ALL STATIONS (67-75) _________

(If two counters operated at one station, include the average count or the count of the most reliable counter.)

GPO 901-239

Because all programs in this documentation anticipate a complete set of 25 cards for each daily sampling record, a pre-edit of card input is required to insure that "dummy" cards are substituted for missing ones. At the RIM Center this is accomplished by machine edit of the input, but users of these programs who will not be processing large volumes of data can more easily insure the completeness of data sets by hand edit. This edit should insure that 25 cards are included in each set and that each card contains, at a minimum, data that will completely identify the sample. This identifying information is found in columns 3-17, with 3-15 used to identify the site and 16-17 used to identify each set of data unique to a particular sampling record. Set numbers run consecutively, with set number 1 assigned to the first sample day, set number 2 assigned to the second sample day, etc. The one exception to this scheme is card 25 of the last set, which is assigned set number 99 to indicate that it is the last card of the last set.

With particular regard to program USEST, experience in RIM has indicated a number of troublesome areas that should be edited carefully before data are processed. The entries in cards 2-13 should be carefully checked to see that all are right-justified. Failure to detect such errors in these cards will result in activity and total use estimates that are much too high. Similar incorrect estimates will result from the same kind of error in fields relating to overnight equipment in card 14. Probably the most common error is found in the field for recording the total seasonal meter count in card 25, set 99. This error obviously results in incorrect output and is the first place that should be reviewed if many estimates seem unreasonable. Note that punch space is provided on card 1 for as many as four different metered counts, shown as stations in exhibit 1. This allows for sampling places having as many as four entrances, and those sampling records showing entries for stations 1, 2, and 3 should show a corresponding total of three site entrance roads on card 25.

Program POC requires that the entries in card 14 showing facility grouping occupancy at 1215 and 1815 must equal the total number of facility groupings shown in card 25. Data serving as input to program USPAT are essentially edited in preparation for running USEST. Program ORGIN requires completion of part II, exhibit 1.

Program USEST

This program uses linear regression techniques to establish the relationship between some form of metered count (independent variable) and number of persons observed on the site and overnight equipment in use to estimate visitor-day use by activities, amount of overnight equipment in use by types, and recreation visits (dependent variables). The regression techniques employed, except for minor variations, can be found in any sound text covering statistical methods. Variations worthy of note are discussed on the following page.

First, the familiar regression equation derived from sample data gathered on a daily basis reads:

$$\hat{y}_{ij} = a_j + b_j x_i \tag{1}$$

and may be employed to estimate daily use on a given site. The components of this equation are defined as:

$\hat{y}_{ij}$ = estimate of dependent variable j (total use, visits, amount of overnight equipment in use, etc.) for the i^{th} day.

a_j = estimate of intercept for dependent variable j.

b_j = estimate of slope for dependent variable j.

x_i = metered count for day i.

For season-long estimates, however, the equation takes the form

$$\hat{T}_j = a_j(N) + b_j(X_s) \tag{2}$$

where

$\hat{T}_j$ = season-long estimate for the j^{th} dependent variable.

N = total number of days in the use season.

X_s = season-long axle count.

Notice that N daily estimates could be calculated by substituting N daily axle readings (if available) for x in equation (1). The sum of these N estimates is equivalent to the $\hat{T}$ estimate computed by equation (2).

Second, in the formula for the standard error of the estimate $\hat{T}$ given by

$$S_{\hat{T}} = N \sqrt{\frac{\text{Residual SS}}{n(n-2)} \left(1 + \frac{1}{n}\right) \left(\frac{N-n}{N}\right)}$$

the term $\left(\frac{N-n}{N}\right)$ is a correction for the finite population for which the estimate is developed.

In exhibit 1 note that 11 activities have been preselected and that there is provision for any one additional activity which might be significant on the site being sampled. The unspecified activity is to be written in by the observer and must remain the same throughout the sampling period. Output is not produced for those activities showing no observed use or for those so correlated to produce negative use estimates. The 11 preselected activities are labeled through use of a Selected Activity

Name and Code Deck (Appendix 5b). This deck is the first of the data to be read into the computer and immediately follows the program and subroutines.

Labeling for the unspecified activity is achieved through use of subroutine LOADAK, which reads activity names and codes from a general activity name and code deck (Appendix 5c) and stores them so they may be easily retrieved according to the activity code entered on the Daily Sampling Record before printing. Subroutines are used for labeling in several other instances in this program. In addition to storing activity names and codes, subroutine LOADAK performs a similar function for site kind names and codes which are read from a general kind name and code deck (Appendix 5c). Subroutines DIST and FOR are used for reading and storing Ranger District names and Forest names (Appendices 5d and 5e), and subroutine GETSUB is used to retrieve this information before printing. All similar labeling achieved in the following programs employs these same subroutines, which are described more completely in subsequent sections and are listed in Appendix 4.

A complete listing of program USEST is shown in Appendix 2a, and a complete illustration of deck setup is shown in Appendix 3a. Exhibit 2 is an example of the output from program USEST. Appendix 1a lists definitions of variable names used in USEST and all other programs. Appendix 1b lists definitions of variable names used in all supporting subroutines.

Program POC

The results of this analysis measure the degree of occupancy of campground and picnic ground units and should be interpreted as indications of trends and apply only to the sample days involved, since no statistical inferences are made from the data. No inference should be attempted because of the high variability of the basic data.

Input for the program is the number of facility groups classified in seven categories (card 14, exhibit 1) including:

1. Vacant.
2. Occupied by gear only.
3. Occupied below design capacity.
4. Occupied within design capacity.
5. Occupied from 0-25 percent above upper limit of capacity.
6. Occupied from 25-75 percent above the upper limit of capacity.
7. Occupied more than 75 percent above the upper limit of capacity.

This information is collected twice daily at 1215 and 1815.

Exhibit 2

```
           USE SAMPLING ANALYSIS WITH STATISTICS FOR CCMPUTING ESTIMATES IN SUCCEEDING YEARS

     REGION NO    4    DAYS IN SEASON=  71     TOTAL METERED COUNT=      8941       OTHER SITES INCLUDED
                                                                                      SITE NO     KIND
     FOREST NO    9    FOREST NAME  HUMBOLDT N F
                                                                                         0          C
     DISTRICT NO  4    DISTRICT NAME  LAMOILLE R D                                       0          0
                                                                                         0          C
     SITE NO    120    SITE NAME  THOMAS CANYON                                          0          C

     SITE KIND  411   CAMPGND-FAMILY TYPE

 VISITOR-DAY USE INFORMATION

          ACTIVITY              REGRESSION COEFFICIENTS     ACTIVITY        VISTOR-DAYS USE    ERROR-TERM
                                           A          B        CODE                           (PERCENT)

     PICNICKING                          2.9C       C.0402     431                   565.8        24.6
        DAY CAMPING                      5.79       0.0684                          1023.1        11.5
        NIGHT CAMPING                   16.82       C.0762                          1876.1        12.5
     CAMPING ALL                        22.61       C.1447     411                  2899.2        11.4




     TOTAL                              25.52       C.1849                          3465.1        12.8



 OTHER,RELATED INFORMATION


                                REGRESSION COEFFICIENTS                     ESTIMATED NO   ERROR TERM
                                           A          B                                     (PERCENT)

       VISITS                           38.22       0.2588                          5027.7        13.3

     OVERNIGHT EQUIPMENT
       AUTO                              2.42      -C.0062                           116.7        37.0
       TENT                              0.66       0.0117                           151.7        15.8
       TRAILER                           1.96       C.0212                           328.5        14.4
```

Each set of data (data for a given site for a particular sample day resulting from individual sampling records) is first stratified by weekdays and weekends/holidays through use of a built-in calendar. The calendar (Appendix 5f) is a deck of cards containing the dates of all weekends and holidays for the season of use and must be changed each year to reflect the correct weekend/holiday dates. Once stratified, the categorized data are accumulated over all sets of data. Final output is next calculated and appears as the average number of groupings occupied and percentage of total facility groupings by category (weekday and weekend/holiday) by strata for both times of day. A listing of this program is shown in Appendix 2b, and a deck setup is shown in Appendix 3b. Exhibit 3 is an example output from program POC.

Program USPAT

This program analyzes sample data resulting in indicators of patterns of use, particularly as it occurs by time of day. Again, no statistical inference should be drawn with respect to use patterns, and the results from this program are valid only for those sample days on which the information was collected.

Input to this program is observed use by time of day (0915 through 2015 and overnight campers) for individual activities. Input is stratified by weekdays and weekends/holidays, then summed over all activities to yield use figures for each time of day. Averages are determined after compilation of all data. Subsequently, these averages are divided by the "PAOT capacity"[3] of the site or complex to generate measures of the percentage of capacity used.

A listing of this program is shown in Appendix 2c, and a deck setup is shown in Appendix 3b. Exhibit 4 is an example output of program USPAT.

Program ORGIN

This program develops indicators of the origin of users of the site. Results are in the form of average number of cars by state, average number of cars per sample day, and percentages by states.

Input is the number of cars by states at two times of day (1215 and 1815). These data also are first stratified by weekdays and weekends/holidays with a built-in calendar (Appendix 5f) which must be changed each year to reflect the correct dates. All data for each site are summed and then divided by number of sample days to yield the average number of cars on the site per sample day. The total number of cars by states divided by the total number of cars for all states gives percentages by states. Other results include a total of all averages by states per day to

---

[3] An instantaneous measure of the number of people who can occupy a recreation place at one time.

Exhibit 3

ANALYSIS OF RECREATION USE DATA FOR SITES STATISTICALLY SAMPLEC IN CY 1969

CAMP AND PICNIC UNIT OCCUPANCY*

REGION 4 FOREST 9 HUMBOLDT N F DISTRICT 6 ELY R D

SITE NAME AND KIND	SITE NO.		OCCUPANCY OF UNITS AS RELATED TO DESIGN CAPACITY							
			VACANT	GEAR ONLY	BELOW LIMITS	WITHIN LIMITS	0-25 ABOVE	25-75 ABOVE	OVER 75 ABOVE	TOTAL
LEHMAN CREEK CAMPGND-FAMILY TYPE SINGLE SITES	60.0									
UNITS OCCUPIED AVE. WEEKDAY		1215	16.4	0.4	0.0	10.1	0.0	0.0	C.C	27.C
PERCENT OCCUPIED			60.8	1.6	0.0	37.6	0.0	0.0	C.C	
		1815	13.4	0.1	0.0	13.4	0.0	0.0	0.0	
PERCENT OCCUPIED			49.7	0.5	0.0	49.7	0.0	0.0	0.0	
UNITS OCCUPIED AVE.SAT/SUN/HOL		1215	18.6	1.4	0.8	5.8	0.4	0.0	0.0	27.0
PERCENT OCCUPIED			68.9	5.2	3.0	21.5	1.5	0.0	0.0	
		1815	18.0	0.8	1.2	7.0	0.0	0.0	0.0	
PERCENT OCCUPIED			66.7	3.0	4.4	25.9	0.0	0.0	0.0	

*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR THE ENTIRE SAMPLE SEASCN

Exhibit 4

ANALYSIS OF RECREATION USE DATA FOR SITES STATISTICALLY SAMPLED IN CY 1969

AVERAGE NUMBER OF VISITORS RECORDED BY TIME OF DAY*

REGION 4 FOREST 9 HUMBOLDT N F DISTRICT 6 ELY R D

SITE NO 60.0 SITE NAME LEHMAN CREEK SITE KIND CAMPGND-FAMILY TYPE SINGLE SITE CAPACITY(PAOT) 300.0

TIME OF DAY	SITE USE IN TERMS OF NUMBER OF VISITORS PRESENT AVE.WEEKDAY	PRCNT CAPACITY	AVE.WKEND/HOL.	PRCNT CAPACITY
0915	36.6	12.2	22.0	7.3
1015	38.0	12.7	19.4	6.5
1115	42.4	14.1	22.0	7.3
1215	50.0	16.7	26.0	8.7
1315	49.4	16.5	27.0	9.0
1415	47.4	15.8	33.2	11.1
1515	47.0	15.7	24.0	8.0
1615	39.3	13.1	24.0	8.0
1715	42.1	14.0	23.0	7.7
1815	45.9	15.3	22.8	7.6
1915	52.1	17.4	28.8	9.6
2015	59.3	19.8	36.0	12.0
OVERNIGHT CAMPERS	57.7	19.2	32.4	10.8
AVE. TOTAL VISITOR HRS/CALENDAR DAY	1242.1		697.0	

*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR THE WHOLE SAMPLE SEASON give an average number of cars per day for the site. Results are calculated for weekdays and weekends/holidays as well as time periods 1215 and 1815 on each sample day. Results of this program may be interpreted as indicators only, and no statistical inference should be made.

A listing and deck setup for program ORGIN is shown in Appendix 2d, and the deck setup is shown in Appendix 3c. Exhibit 5 displays example output from this program.

Subroutine LOADAK

The function of this subroutine is to read and store activity or kind names for retrieval. Input to this subroutine is either a general activity name and code deck or a general kind name and code deck, depending on which names are being stored. Formats for these decks are given in Appendix 5c. Because subroutine logic is the same for processing activity and kind information, only the procedures for storing activity names are given here.

As each card in the name deck is read, a counter variable NK is incremented by 1. The array KODES is indexed by the activity code just read and is assigned the value for NK generated at each execution of the read statement. Next, the array KLOD is indexed by NK and is assigned the value just read for activity code. Finally, the array NAMES is indexed by NK and stores the activity name just read. The procedure continues with NK being increased by 1 with each execution of the read statement until a blank card is read and signals a return to the main program.

As the subroutine returns to the main program, KODES, NAMES, NK, and KLOD are recognized by the main program as ACTS1, ACTS2, ACTS3, and ACTS4. When a specific activity name is to be retrieved, the variable NA is set equal to ACTS1 as indexed by the activity code in question. This sets NA equal to the count previously assigned to this activity by LOADAK. NA is then used as an index to ACTS2 in retrieving the proper activity name.

There are several approaches for storing name data simpler than that described for LOADAK, as well as for other subroutines subsequently described, but the procedure involved in the subroutines described here has two advantages. First, this approach reduces the amount of memory that must be reserved for the storage of names. And second, it provides great flexibility in making changes in the name decks being stored. Program dimensions are such that names can be added, deleted, or changed without the need for any program changes, and program logic requires no particular order of the data decks.

Subroutines FOR and DIST

Subroutines FOR and DIST are employed to store Forest and District names for retrieval by subroutine GETSUB. Because the logic for subroutines FOR and DIST is the same, only subroutine FOR is described here.

Exhibit 5

ANALYSIS OF RECREATION USE DATA FOR SITES STATISTICALLY SAMPLED IN CY 1969

VEHICLES BY STATE OF ORIGIN *

RECION 4 FOREST 9 HUMBOLDT N F DISTRICT 6 ELY R C

SITE NO 60.C SITE NAME LEHMAN CREEK SITE KIND CAMPGNC-FAMILY TYPE SINGLE SITE CAPACITY(PAOT) 300.

STATE NAME	WEEKDAYS AVE.NO.CARS TALLIED ON SAMPLE DAYS 1215	 1815	 PER CENT ALL CARS TALLIED ON SAMPLE DAYS 1215	 1815	WEEKENC/HCLICAY AVE.NO.CARS TALLIEC ON SAMPLE DAYS 1215	 1815	 PER CENT ALL CARS TALLIED ON SAMPLE DAYS 1215	 1815
ALABAMA	0.0	0.1	0.0	1.1	0.C	0.0	0.0	0.0
CALIFORNIA	2.6	3.4	18.0	26.1	1.8	2.6	25.0	28.9
COLORADO	0.0	0.6	0.0	4.3	0.0	0.0	0.0	C.C
FLORIDA	0.1	0.3	1.0	2.2	0.C	0.0	0.0	C.C
GEORGIA	0.0	0.1	0.0	1.1	0.C	0.0	0.0	C.0
ILLINOIS	0.0	0.4	0.0	3.3	0.C	0.0	0.0	0.0
MICHIGAN	0.0	0.3	0.0	2.2	0.0	0.2	0.0	2.2
NEVADA	7.4	5.7	52.0	43.5	4.8	4.8	66.7	53.3
NEW MEXICO	1.0	1.1	7.0	8.7	0.C	0.0	0.0	C.0
UTAH	2.7	0.4	19.0	3.3	0.2	1.0	2.8	11.1
VERMONT	0.0	0.1	0.0	1.1	0.0	0.0	0.0	C.C
WASHINGTON	0.0	0.0	0.0	0.0	0.4	0.4	5.6	4.4
WISCONSIN	0.4	0.4	3.0	3.3	0.C	0.0	0.0	C.0
TOT ALL STATES	14.3	13.1	100	100	7.2	9.0	100	1CC

*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR THE WHOLE SAMPLE SEASON

After storage locations have been cleared, the first card in the Forest Name Deck (Appendix 5d) is read and includes Region number, coded as N1; Forest number, coded as N2; and Forest name, coded as NAME. Subsequently, a counter variable, NK, is assigned a unique number generated for each Forest. This unique number is determined by multiplying Region number by 100 and adding Forest number; e.g., the number 102 is Forest 2 of Region 1 and the number 1002 is Forest 2 of Region 10. Then the array NAMES, subscripted by NK, is assigned the Forest name just read. This procedure continues until a blank card is read to signal a return to the main program. When Forest and District names are not desired, two blank cards represent the Forest and District name decks.

After storage is complete and the subroutine returns control to the main program, the subroutine arguments KODES, NAMES, and NK are recognized by the main program as FORST1, FORST2, and FORST3 and are used in retrieving names by subroutine GETSUB.

Subroutine GETSUB

This subroutine functions to retrieve Forest and District names after their storage by subroutines FOR and DIST. When this subroutine is called to retrieve Forest names, the main program gives it values of FORST1, FORST3, NF, and 200 which it recognizes as KODES, NK, NPOINT, and NDEM. NDEM is used in GETSUB to dimension the array KODES which contains all unique Forest numbers assigned previously. With NK used as the termination point in a do loop, NSUB is set equal to the variable index of the do loop, and as NSUB is incremented it is used as an index for KODES. KODES (NSUB) is compared with NPOINT until they are equal. When this occurs, NSUB is returned to the main program and is the proper index to FORST2, the array containing Forest names. Should the do loop be satisfied before KODES (NSUB) equals NPOINT, a value of NK + 1 is assigned to NSUB which results in retrieval of a blank Forest name.

LITERATURE CITED

(1) Bury, Richard L., and Ruth Margolis
1964. A method for estimating current attendance on sets of campgrounds...a pilot study. Pac. Southwest For. & Range Exp. Stn., U. S. For. Serv. Res. Note PSW-42, 6 pp.

(2) Cushwa, Charles T., and Burd S. McGinnes
1964. Sampling procedures and estimates of year-round recreation use on 100 square miles of the George Washington National Forest. Twenty-Eighth North Am. Wildl. & Nat. Resour. Conf. Trans. 1963: 457-465.

(3) James, George A.
1966. Instructions for using traffic counters to estimate recreation visits and use on developed sites. USDA For. Serv. Southeast. For. Exp. Stn., 12 pp.

(4) ________ and Robert A. Harper
1965. Recreation use of the Ocala National Forest in Florida. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. SE-18, 28 pp.

(5) ________ and Robert K. Henley
1968. Sampling procedures for estimating mass and dispersed types of recreation use on large areas. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. SE-31, 15 pp.

(6) ________ and Gary L. Tyre
1967. Use of water-meter records to estimate recreation visits and use on developed sites. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Note SE-73, 3 pp.

(7) USDA Forest Service
1967. RIM Handbook. FSH 2309.11, 192 pp.

(8) ________
1968. Recreation information management. A computer-oriented system for the management of information about people, places, and things over periods of time. In-Serv. Train. Guide, 127 pp.

(9) Wagar, J. Alan
1964. Estimating numbers of campers on unsupervised campgrounds. Northeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. NE-18, 16 pp.

(10) ________
1969. Estimation of visitor use from self-registration at developed recreation sites. Intermt. For. & Range Exp. Stn., USDA For. Serv. Res. Pap. INT-70, 27 pp.

Appendix 1a

Definitions of Program Variable Names

ACTIVE	Array which stores preselected activity names.
ACTS1	Argument to subroutine LOADAK (see KODES, Appendix 1b).
ACTS2	Argument to subroutine LOADAK (see NAMES, Appendix 1b).
ACTS3	Argument to subroutine LOADAK (see NK, Appendix 1b).
ACTS4	Argument to subroutine LOADAK (see KLOD, Appendix 1b).
AY	Array containing all "a" regression coefficients used in the equations for visits, activity use and total use, and overnight facility-use.
BY	Array containing all "b" regression coefficients used in the equations for visits, activity use and total use, and overnight facility-use.
CAL	Array containing all dates of weekend days and holidays, used to determine when a sample day occurred. Data are read into this array from a card deck which must be updated annually.
CARD	Array containing count of people entering the site, numbers of people engaging in any of 12 activities (11 preselected and one selected by sampler), and the code of the activity selected by the sampler for each of 12 times of day (0900 through 2000).
CARS	Array containing numerical state codes and numbers of cars observed on the site, by state and time of day (1215 and 1815 hours).
CODE	Array used to store preselected activity codes.
DATE	Date sample was taken.
DISTR1	Argument to subroutine DIST (see KODES, Appendix 1b).
DISTR2	Argument to subroutine DIST (see NAMES, Appendix 1b).
DISTR3	Argument to subroutine DIST (see NK, Appendix 1b).
DISTRT	Variable name for District number.
DSUB	Argument to subroutine GETSUB (see NSUB, Appendix 1b).

ENT	Four-element array containing daily axle count (independent variable) for each site entrance.
ERRY	Array containing percent error of "y" estimates.
ESTY	Array containing regression estimates of "y" (visits and use).
FAC1	Array used in reading the number of facility groupings occupied at six different occupancy levels at 1215 hours.
FAC2	Array used in reading the number of facility groupings occupied at six different occupancy levels at 1815 hours.
FACGRP	Variable identifying the total number of facility groupings.
FMULT	Multiplier used to convert the instantaneous estimate of overnight visitors to an estimate reflecting total visitor presence over the 12 hours available for night use.
FOREST	Variable name for Forest number.
FORST1	Argument to subroutine FOR (see KODES, Appendix 1b).
FORST2	Argument to subroutine FOR (see NAMES, Appendix 1b).
FORST3	Argument to subroutine FOR (see NK, Appendix 1b).
FSUB	Argument to subroutine GETSUB (see NSUB, Appendix 1b).
HAVE	Array containing the average number of cars observed per weekend/holiday sample for each state and by time of day (1215 and 1815 hours).
HAVIS	Average number of visitor-days per holiday-weekend sample.
HFAC1	Array containing facility unit occupancy on weekends/holidays at 1215 hours. First used as a summary array and later as an array for average occupancy.
HFAC2	Array containing facility unit occupancy on weekend/holidays at 1815 hours. First used as a summary array and later as an array for average occupancy.
HORIGIN	Array containing summary of numbers of cars, by origin (state) and time of day (1215 and 1815 hours) for weekends/holidays.
HPCAP	Array showing percentage of site capacity utilized, by time of day (1215 and 1815 hours) for weekends/holidays.

HPCNT	Percentage of average number of cars from all origins (states) for individual origins, by time of day (1215 and 1815 hours) for weekend/holiday samples.
HPERS	Array containing number of persons observed on the site on weekend/holidays, by time of day (1215 and 1815 hours). Used first as a summary area for persons observed by time of day and later to store the average number of persons by time of day.
HPOC1	Percentage of total facility units occupied at various occupancy levels on weekends/holidays at 1215 hours.
HPOC2	Percentage of total facility units occupied at various occupancy levels on weekends/holidays at 1815 hours.
HTOT	Array containing average number of cars observed on the site, by time of day (1215 and 1815 hours) for weekends and holidays.
HTOVIS	Total number of visitor-days observed for the site for all weekend and holiday samples.
IACT	Variable name for write-in activity.
INDEX	Variable name for state number used as an index to the arrays WORIGIN and HORIGIN.
JL	Index used in finding amount points in the array CARS when totaling into the arrays HORIGIN and WORIGIN.
KIND1	Argument to subroutine LOADAK (see KODES, Appendix 1b).
KIND2	Argument to subroutine LOADAK (see NAMES, Appendix 1b).
KIND3	Argument to subroutine LOADAK (see NK, Appendix 1b).
KIND4	Argument to subroutine LOADAK (see KLOD, Appendix 1b).
KTECH	Array containing description of site from which information came (single site or site complex).
MEANX	Average number of daily axle counts over all sample days.
MEANY	Average number of observations for all dependent variables.
NA	Identifies the order in which a particular activity name and code have been read and stored by subroutine LOADAK. Once identified, it is used as an index to array ACTS2 which contains activity names (see NK and NAMES, Appendix 1b).

NAME	Read area variable for site name.
NBLANK	Read area used to read past data not necessary to program.
ND	Argument to subroutine GETSUB used in retrieving District names. It identifies a unique code for each District (see NPOINT, Appendix 1b).
NEQUIP	Counts of the types of overnight equipment in use.
NF	Argument to subroutine GETSUB used in retrieving Forest names. It identifies a unique code for each Forest (see NPOINT, Appendix 1b).
NHD	Number of weekend/holiday days on which sample was taken.
NITCAM	Number of overnight campers (treated as a separate activity and also added to total-day camping to derive a total camping estimate).
NK	Identifies the order in which a particular kind name and code has been read and stored by subroutine LOADAK. Once identified, it is used as an index to array KIND2 which contains kind names (see NK and NAMES, Appendix 1b).
NNN	Integer equivalent to TSDAYS, the number of days in the season of use.
NNXS	Integer equivalent to SAXLE, the season-long metered count.
NOPERS	Array containing number of persons observed on site by the activity in which they are engaged.
NOROADS, NORODS	Number of site entrances.
NOSAMP	Number of sample days per site.
NOSITE	Counter variable to go to a new page after output for two sites has been printed per page.
NSD	Number of sample days.
NWD	Number of weekdays on which a sample was taken.
ODIS	See OREG.
OFOR	See OREG.
OKIND	Storage and print variable name for kind code of principal site.

ONAME	Storage area array for site name.
ONIT	Storage variable name for the number of overnight campers.
OREG	Storage and print variable names for Region, Forest, and District numbers in program 23.301. In programs 23.304-306 they are also used as compare variables for determining breaks to new pages of output.
OSITE	Storage and print variable name for principal site number.
OTECH	Storage variable name for technique number.
OTHERS	Storage area array for the numbers and kind codes of other sites included in the sample (ordinarily this occurs only for site complexes).
OTHSIT	Read area array for the numbers and kind codes of other sites included in the sample (ordinarily this occurs only for site complexes).
PAOT	Persons at one time--a measure of instantaneous capacity.
PKIND	Variable name for kind code of principal site.
PSITE	Read variable name for principal site number.
REG	Variable name for Region number in programs 23.304-306.
REGION	Variable name for Region number in program 23.301.
SAXLE	Storage area for season-long axle count.
SE	Array containing standard errors of estimates.
SET	Code number used to distinguish data gathered on one sample day from those gathered on another.
SITE	Variable name for principal site number in programs 23.304-306.
SMSQX	Sum of squared daily axle counts. It is the uncorrected sum of squares of the independent variable.
SMSQY	Array containing sample "y" observations for all variables squared for each sample day and then summed. This is the uncorrected sums of squares for the dependent variables.
SMX	Sum of daily axle counts over all sample days. It is the sum of the independent variable.

SMXY	Array containing daily axle count observations multiplied by sample "y" observations for all variables. It is the uncorrected sum of cross-products.
SMY	Array containing number of visitor-days by activity, total visitor-days, and total visit count over all sample days and is the sum of the dependent variables.
SNO	Site number in floating point to one decimal place.
SPXY	Array containing corrected sums of cross-products.
SSX	Corrected sum of squares for the independent variable.
SSY	Array containing corrected sums of squares for the dependent variables.
STE	Array containing state names.
TALLY	Counter variable for number of sites processed.
TDCNT	Total daily axle count (independent variable) for all site entrances.
TECH, TECHNO	Read variable name for technique. Indicates whether data resulted from a single site or a site complex.
TEST	Value used to initialize compare variables and to zero all summary points. This value is also used in signaling end of data.
TMOFDA	Data array at times of day (0915 through 2015 hours).
TNE	Variable name for number of entrances.
TNPERS	Array which first contains total number of persons by activity for each sample day. Total number of persons is subsequently transformed to visitor-days.
TODAYS	Total number of days in use season.
TSAXLE	Read variable name for season-long axle count.
TSDAYS	Storage variable name for number of days in the season.
WAVE	Array containing the average number of cars observed per weekday sample for each state and by time of day (1215 and 1815 hours).
WAVIS	Average number of visitor-days per weekday sample.

WFAC1	Array containing facility unit occupancy on weekdays at 1215 hours. First used as a summary array, then as an array for average occupancy.
WFAC2	Array containing facility unit occupancy on weekdays at 1815 hours. First used as a summary array, then as an array for average occupancy.
WORIGIN	Array containing summary of number of cars, by origin (state) and time of day (1215 and 1815 hours) for weekdays.
WPCAP	Array showing the percentage of total site capacity being utilized, by time of day for weekday samples.
WPCNT	Percentage of the average number of cars from all origins (states) for individual origins, by time of day (1215 and 1815 hours) for weekday samples.
WPERS	Array containing the number of persons observed on the site on weekday samples, by time of day. Used first as a summary of all persons observed by time of day and later as average number by time of day.
WPOC1	Percentage of total facility units occupied at the various levels of occupancy on weekday samples at 1215 hours.
WPOC2	Percentage of total facility units occupied at the various levels of occupancy on weekdays at 1815 hours.
WTOT	Total number of cars observed on the site, by time of day (1215 and 1815 hours) for weekday samples.
WTOVIS	Total number of visitor-days observed for the site for all weekday samples.

Appendix 1b

Definitions of Subroutine Variable Names

KLOD	Array storing kind/activity codes and indexed by NK, the order on which the codes are loaded. Corresponds to ACTS4 or KIND4 of main program.
KOD	Kind/activity code read by subroutine LOADAK.
KODES	In subroutine LOADAK, an array which is indexed by kind/activity codes and stores NK, the order in which the codes are loaded. Corresponds to argument ACTS1 or KIND1 of main program. In subroutines DIST and FOR this array is indexed by NK and stores a unique code for each District or Forest. This code is subsequently used as a return point in subroutine GETSUB when retrieving Forest and District names. In this case, KODES corresponds to arguments FORST1 or DISTR1 in main program.
NAME	Kind/activity name read by LOADAK.
NAMES	Array storing kind/activity names, District names, or Forest names and indexed by NK, the order on which the names are loaded. Corresponds to ACTS2 or KIND2 of main program for LOADAK, DISTR2 for DIST, and FORST2 for FOR.
NDEM	Dimension of the array KODES used in GETSUB. It is set at 200 when GETSUB is being used to retrieve Forest names and 900 when retrieving District names.
NK	Order on which codes and names are loaded. Corresponds to ACTS3 or KIND3 of main program for LOADAK, DISTR3 for DIST, and FORST3 for FOR.
NPOINT	A unique code for an individual Forest or District used in GETSUB for retrieval of Forest or District names.
NSUB	Index value for the array KODES in GETSUB. When terminated, GETSUB returns a particular value for NSUB which the main program recognizes as DSUB or FSUB, depending on whether GETSUB has been called in retrieving District or Forest names. This value is then used as an in index for either array DISTR2 or FORST2.

Appendix 2a

Listing of Program USEST

```
PROGRAM USEST
      DIMENSION NBLANK(10),CODE(17,2),ACTIV(17,4)
      DIMENSION KIND1(999),ACTS1(999),KIND2(60,6),A
     1CTS2(60,6),KIND4(60),ACTS4(60),FORST1(200),FORST2(200,4),DISTR1(90
     20),DISTR2(900,4),NAME(7),OTHSIT(8),ENT(4),CARD(12,14),        NEQUI
     3P(3),TNPERS(19),SMY(19),SMSQY(19),SMXY(19),MEANY(19),SPXY(19),SSY(
     419),BY(19),AY(19),ESTY(19),SE(19),ERRY(19),ONAME(7),OTHERS(8)
      INTEGER TEST,DISTR3,FORST3,ACT3,FSUB,DSUB,FORST1,FORST2,DISTR1,DI
     1STR2,REGION,FOREST,DISTRT,PSITE,PKIND,OTHSIT,TECHNO,DAY,YEAR,OKIND
     2,OSITE,ODIS,OFOR,OREG,ONAME,OTHERS,OTECH,ACTIV,CODE,
     5ACTS1,ACTS2,ACTS3,ACTS4
      REAL NEQUIP
      REAL MAXDIF,MINDIF
      REAL NITCAM,NOSAMP,MEANX,MEANY
C
C READ FIXED ACTIVITY CODES AND NAMES
C
      DO 120 I=1,17
      READ(5,100) (ACTIV(I,J),J=1,4),(CODE(I,K),K=1,2)
 100  FORMAT(3A6,A3,A6,A2)
 120  CONTINUE
C LOAD ACTIVITY AND KINDS INTO MEMORY
C
      CALL LOADAK(KIND1,KIND2,KIND3,KIND4)
C
      CALL LOADAK(ACTS1,ACTS2,ACTS3,ACTS4)
C
C INITIALIZE CHECK AND SUMMARY POINTS
C
      TEST=1
      TALLY=0
      SUMDIF=0
      MAXDIF=0
      MINDIF=99999.9
      KIND3=0
      DISTR3=0
      FORST3=0
      ACTS3=0
      FSUB=1
      DSUB=1
      TNENT=0
      NSD=0
      SMX=0
      SMSQX=C
      TDCNT=0
      DO 10 I=1,21
      SMY(I)=0
      SMSQY(I)=0
      SMXY(I)=0
      TNPERS(I)=0
   10 CONTINUE
      NOSAMP=0
C
C LOAD FOREST AND DISTRICT NAMES
C
      CALL FOR (FORST1,FORST2,FORST3)
      CALL DIST(DISTR1,DISTR2,DISTR3)
C
C READ AREA FOR COMPLETE SET OF DATA
C
   20 CONTINUE
   22 READ(5,21) REGION,FOREST,DISTRT,PSITE,PKIND,(NAME(I),I=1,7),(ENT(I
     1),I=1,4)
      IF(REGION.EQ.99) GO TO 880
   21 FORMAT(2X,3I2,I4,I3,2X,6A6,A5,4F5.0)
      DO 23 I=1,12
      READ(5,24) (CARD(I,J),J=1,14)
   24 FORMAT(17X,4F5.0,9F4.0,F3.0)
   23 CONTINUE
      READ(5,25) NITCAM,(NEQUIP(I),I=1,3)
   25 FORMAT(59X,F5.0,3F3.0)
      DO 28 I=1,10
      READ(5,27) NBLANK(I)
   27 FORMAT(I2)
   28 CONTINUE
      READ(5,26) TECHNO,(OTHSIT(J),J=1,8),TODAYS,TNE,TSAXLE
   26 FORMAT(17X,I2,4(I4,I3),12X,F3.0,3X,F1.0,F9.0)
      IF(TEST.EQ.1)GO TO 800
C
C CHECK FOR NEW SITE
C
   30 IF(OKIND.NE.PKIND)GO TO 600
      IF(OSITE.NE.PSITE)GO TO 600
      IF(ODIS.NE.DISTRT)GO TO 600
      IF(OFOR.NE.FOREST)GO TO 600
      IF(OREG.NE.REGION)GO TO 600
      DO 804 J=1,8
      OTHERS(J)=IABS(OTHSIT(J))
  804 CONTINUE
      DO 32 I=1,19
      TNPERS(I)=0
   32 CONTINUE
      IF(TODAYS.GT.0.)TSDAYS=TODAYS
      TDCNT=0
C
C CONVERT DATA TO VISTOR DAYS
C GENERATE SUMS,SUM OF SQUARES,
C SUM OF CROSS PRODUCTS
C
      DO 34 I=1,12
      DO 34 J=2,13
      TNPERS(J)=TNPERS(J)+CARD(I,J)
      IF(CARD(I,14).GT.0.)IACT=CARD(I,14)
   34 CONTINUE
      DO 36J=2,13
      TNPERS(J)=TNPERS(J)/12.
   36 CONTINUE
      TNPERS(14)=NITCAM
      TNPERS(15)=TNPERS(3)+NITCAM
      DO 35 I=2,14
      TNPERS(16)=TNPERS(16)+TNPERS(I)
   35 CONTINUE
      DO39 I=17,19
      TNPERS(I)=NEQUIP(I-16)
   39 CONTINUE
      NOSAMP=NOSAMP+1.
      DO 37 I=1,4
      IF(ENT(I).GT.0.)TNENT=TNENT+1.
      TDCNT=TDCNT+ENT(I)
   37 CONTINUE
      DO 40 I=1,12
      TNPERS(1)=TNPERS(1)+CARD(I,1)*4.*TNENT
   40 CONTINUE
      TNENT=0
      SMX=SMX+TDCNT
      SMSQX=SMSQX+TDCNT**2
      DO 42 I=1,19
      SMY(I)=SMY(I)+TNPERS(I)
      SMSQY(I)=SMSQY(I)+TNPERS(I)**2
      SMXY(I)=SMXY(I)+TDCNT*TNPERS(I)
   42 CONTINUE
      IF(TSAXLE.GT.O.)SAXLE=TSAXLE
      GO TO 20
C
C GENERATE MEANS,CORR.SUM SQUARES AND CROSS PRODUCTS
C A AND B COEFFICIENTS, STANDARD ERROR AND ERROR TERMS
C
  600 MEANX=SMX/NOSAMP
      SSX=SMSQX-SMX**2/NOSAMP
      DO 602 I=1,19
      MEANY(I)=SMY(I)/NOSAMP
      SPXY(I)=SMXY(I)-(SMX*SMY(I)/NOSAMP)
      SSY(I)=SMSQY(I)-SMY(I)**2/NOSAMP
      BY(I)=SPXY(I)/SSX
      AY(I)=MEANY(I)-BY(I)*MEANX
      ESTY(I)=AY(I)*TSDAYS+BY(I)*SAXLE
      SE(I)=SQRT(((SMSQY(I)-AY(I)*SMY(I)-BY(I)*SMXY(I))/(NOSAMP*(NOSAMP-
     12.)))*(1.+1./NOSAMP)*((TSDAYS-NOSAMP)/TSDAYS))*TSDAYS
      ERRY(I)=(SE(I)/ESTY(I))*100.
  602 CONTINUE
C
C WRITE AREA FOR DOUBLE SAMPLE
C
      NF=OREG  *100+OFOR
      CALL GETSUB(FORST1,FORST3,NF,FSUB,200)
      ND=NF*100+ODIS
      CALL GETSUB(DISTR1,DISTR3,ND,DSUB,900)
      NK=KIND1(OKIND)
      NNN=TSCAYS
      NNXS=SAXLE
      WRITE(6,699)
  699 FORMAT(1H1,105H                                  USE SAMPLING ANALYSIS WITH
     1STATISTICS FOR COMPUTING ESTIMATES IN SUCCEEDING YEARS)
      WRITE(6,700) OREG,NNN,NNXS
  700 FORMAT(1H0,16X,12HREGION NO   ,I2,19H    DAYS IN SEASON=,I4,25H
     1  TOTAL METERED COUNT=,I9,7X,24HOTHER SITES INCLUDED    )
      WRITE(6,701)
  701 FORMAT(1H ,96X,16HSITE NO     KIND)
      WRITE(6,702) OFOR,(FORST2(FSUB,I),I=1,4)
  702 FORMAT(1H ,16X,12HFOREST NO   ,I2,4X,13HFOREST NAME  ,3A6,A3)
      WRITE(6,703)(OTHERS(I),I=1,2)
  703  FORMAT(1H ,96X,I4,8X,I3)
      WRITE(6,704) ODIS,(DISTR2(DSUB,I),I=1,4),(OTHERS(I),I=3,4)
  704 FORMAT(17X   12HDISTRICT NO ,I2,4X,15HDISTRICT NAME  ,3A6,A2,27X,
     1I4,8X,I3)
      WRITE(6,703) (OTHERS(I),I=5,6)
      WRITE(6,705) OSITE,(ONAME(I),I=1,6),(OTHERS(I),I=7,8)
  705 FORMAT(1H ,16X,10HSITE NO   ,I4,4X,11HSITE NAME  ,5A6,A1,20X,I4,8X
     1,I3)
      WRITE(6,706) OKIND,(KIND2(NK,I),I=1,4)
  706 FORMAT(1H0,16X,11HSITE KIND  ,I3,3X3A6,A3)
      WRITE(6,707)
  707 FORMAT(1H0,7X,27HVISITOR-DAY USE INFORMATION)
      WRITE(6,708)
  708 FORMAT(1H0,23X,8HACTIVITY,11X,23HREGRESSION COEFFICIENTS,4X,8HACTI
     1VITY,7X,16HVISTOR-DAYS USE ,2X,10HERROR-TERM)
```

```
      WRITE(6,709)
  709 FORMAT(1H ,49X,1HA,10X,1HB,11X,4HCODE,27X,9H(PERCENT)//)
  721 DO 725 I=2,12
      IF(ESTY(I).LE.0.)GO TO 724
      WRITE(6,710) (ACTIV(I-1,J),J=1,4),AY(I),BY(I),(CODE(I-1,K),K=1,2),
     1ESTY(I),ERRY(I)
  724 IF(I.NE.3) GO TO 725
      IF(ESTY(14).GT.0.)WRITE(6,710) (ACTIV(13,J),J=1,4),AY(14),BY(14),(
     1CODE(13,K),K=1,2),ESTY(14),ERRY(14)
  710 FORMAT(1H ,16X,3A6,A3,4X,F11.2,2X,F11.4,4X,A6,A3,10X,F11.1,F11.
     11)
      IF(ESTY(15).GT.0.)WRITE(6,710) (ACTIV(14,J),J=1,4),AY(15),BY(15),(
     1CODE(14,K),K=1,2),ESTY(15),ERRY(15)
  725 CONTINUE
      DO 716 I=1,5
      WRITE(6,717)
  717 FORMAT(1H )
  716 CONTINUE
      IF(ESTY(13).EQ.0.) GO TO 730
      IF(IACT.LE.0.OR.IACT.GE.999) GO TO 730
      NA=ACTS1(IACT)
      IF(NA.EQ.0)GO TO 730
      WRITE(6,715) (ACTS2(NA,I),I=1,4),AY(13),BY(13),IACT,ESTY(13),ERRY(
     113)
  715 FORMAT(1H ,16X,3A6,A3,4X,F11.2,2X,F11.4,9X,I3,10X,F11.1,1X,F11.1)
  730 WRITE(6,710) (ACTIV(12,J),J=1,4),AY(16),BY(16),(CODE(12,K),K=1,2),
     1ESTY(16),ERRY(16)
      WRITE(6,718)
  718 FORMAT(///7X,25HOTHER,RELATED INFORMATION///43X,23HREGRESSION COEF
     1FICIENTS,22X,12HESTIMATED NO,3X,10HERROR TERM/50X,1HA,10X,1HB,42X,
     29H(PERCENT))
      WRITE(6,719) AY(1),BY(1),ESTY(1),ERRY(1)
  719 FORMAT(1H0,19X,6HVISITS16X,F11.2,2X,F11.4,23X,F11.1,    F11.1//)
      WRITE(6,720)
  720 FORMAT(1H ,16X,19HOVERNIGHT EQUIPMENT)
      DO 735 I=17,19
      IF(ESTY(I).LE.0.) GO TO 735
      WRITE(6,722) (ACTIV(I-2,J),J=1,4), AY(I),BY(I),ESTY(I),ERRY(I)
  722 FORMAT(20X,    3A6,A3,1X,F11.2,2X,F11.4,23X,F11.1,F11.1)
  735 CONTINUE
  8CC IF(TEST.LT.2) TEST=2
C
C COMPARE AREAS INITIALIZED
C AND SUMMARY POINTS ZEROED
C
      OREG=REGION
      OFOR=FOREST
      ODIS=DISTRT
      OSITE=PSITE
      OKIND=PKIND
      DO 802I=1,6
      ONAME(I)=NAME(I)
  802 CONTINUE
      OTECH=TECHNO
      OTDAYS=TODAYS
      TNENT=0
      NOSAMP=0
      SMX=0
      SMSQX=0
      IACT=999
      DO 808 I=1,19
      SMY(I)=0
```

Appendix 2a (continued)

```
      SMSQY(I)=0
      SMXY(I)=0
  808 CONTINUE
C
C CHECK FOR END OF DATA AND
C ENDFILE AREA
      IF(TEST.EQ.3) GO TO 900
      GO TO 30
  880 TEST=3
      GO TO 600
  900 STOP
      END
```

Appendix 2b

Listing of Program POC

```
PROGRAM POC
      DIMENSION CAL(38),FORST1(200),FORST2(200,4),DISTR1(900),DISTR2(900
     1,4),KIND1(999),KIND2(60,6),KIND4(60),KTECH(2,2)
      DIMENSION NAME(7),NOPERS(12,14),FAC1(7),FAC2(7),CARS(10,18),WFAC1(
     17),WFAC2(7),HFAC1(7),HFAC2(7),WPOC1(7),WPOC2(7),HPOC1(7),HPOC2(7)
      REAL NOPERS,NORODS,NWD,NHD
      INTEGER CAL
      INTEGER REG,          SITE,SET,TECH,DATE,OREG,OFOR,ODIS,FORST1,FORS
     1T2,FORST3,DISTR1,DISTR2,DISTR3,FSUB,CSUB
      INTEGER FOREST,DISTRT
      DATA (KTECH(1,I),I=1,2)/6HSINGLE,6H SITES/
      DATA (KTECH(2,I),I=1,2)/6HSITE C,6HOMPLEX/
      DO 2 I=1,37
      READ(5,1)CAL(I)
    1 FORMAT(I6)
    2 CONTINUE
      CALL LOADAK(KIND1,KIND2,KIND3,KIND4)
      CALL FOR(FORST1,FORST2,FORST3)
      CALL DIST(DISTR1,DISTR2,DISTR3)
      NWD=0
      NHD=0
      DO 3 I=1,7
      WFAC1(I)=0
      WFAC2(I)=C
      HFAC1(I)=0
      HFAC2(I)=0
    3 CCNTINUE
      OREG=C
    8 CCNTINUE
    9 READ(5,10) REG,FOREST,DISTRT,SITE,KIND,SET,(NAME(I),I=1,7)
      IF(REG.EQ.99) GO TO 5C0
   1C FORMAT(2X,3I2,I4,I3,I2,6A6,A5)
      DO 20I=1,12
      READ(5,22)(NOPERS(I,J),J=1,14)
   2C CONTINUE
   22 FORMAT(17X,4F5.0,9F4.0,F3.0)
      READ(5,24)(FAC1(I),I=1,7),(FAC2(J),J=1,7),ONIT,DATE
   24 FORMAT(17X,14F3.C,F5.0,9X,I6)
      DO 30 I=1,10
      READ(5,32)(CARS(I,J),J=1,18)
   30 CONTINUE
   32 FORMAT(17X,6(F2.C,F4.C,F4.0))
      READ(5,34)SET,TECH,FACGRP,NORODS,SAXLE
   34 FORMAT(15X,2I2,43X,F3.0,F1.0,F9.0)
      IF(KIND.EQ.411.OR.KIND.EQ.412.OR.KIND.EQ.431.CR.KIND.EQ.432)GO TO
     136
      GO TO 8
   36 TECH=TECH-10
      DO 40 I=1,38
      IF(DATE.EQ.CAL(I)) GO TO 50
   4C CONTINUE
C     ***WEEKDAY***
      NWD=NWD+1.
      DO 42 I=1,7
      WFAC1(I)=WFAC1(I)+FAC1(I)
      WFAC2(I)=WFAC2(I)+FAC2(I)
   42 CONTINUE
      IF(SET.EQ.99)GO TO 60
      GO TO 8
C     ***HOLIDAY/WEEKENC***
   5C NHD=NHD+1.
   DO 52 I=1,7
   HFAC1(I)=HFAC1(I)+FAC1(I)
   HFAC2(I)=HFAC2(I)+FAC2(I)
52 CONTINUE
   IF(SET.EQ.99)GO TO 60
   GO TO 8
60 DO 62 I=1,7
   WFAC1(I)=WFAC1(I)/NWD
   WFAC2(I)=WFAC2(I)/NWD
   HFAC1(I)=HFAC1(I)/NHD
   HFAC2(I)=HFAC2(I)/NHD
   WPOC1(I)=(WFAC1(I)/FACGRP)*100.
   WPOC2(I)=(WFAC2(I)/FACGRP)*100.
   HPOC1(I)=(HFAC1(I)/FACGRP)*100.
   HPOC2(I)=(HFAC2(I)/FACGRP)*100.
62 CONTINUE
   IF(REG.EQ.OREG.AND.FOREST.EQ.OFOR.AND.DISTRT.EQ.ODIS) GO TO  63
   OREG=REG
   OFOR=FOREST
   ODIS=DISTRT
   WRITE(6,94)
   NOSITE=0
63 IF(NOSITE.NE.0)GO TO 80
64 WRITE( 6,66)
66 FORMAT(1H1,30X,74HANALYSIS OF RECREATION USE DATA FOR SITES STATIS
  1TICALLY SAMPLED IN CY 1969)
   WRITE( 6,68)
68 FORMAT(1H0,51X,31HCAMP AND PICNIC UNIT OCCUPANCY*)
   NF=OREG*100+OFOR
   CALL GETSUB(FORST1,FORST3,NF,FSUB,200)
   ND=NF*100+ODIS
   CALL GETSUB(DISTR1,DISTR3,ND,DSUB,900)
   WRITE(6,70) OREG,OFOR,(FORST2(FSUB,I),I=1,4),ODIS,(DISTR2(DSUB,I),
  1I=1,4)
70 FORMAT(1H0,20X,6HREGION,I3,3X,6HFOREST,I3,2X,3A6,A2,2X,8HDISTRICT,
  12X,I3,2X,3A6,A2)
   WRITE( 6,72)
72 FORMAT(1H0,10X,18HSITE NAME AND KIND,14X,8HSITE NO.,15X,48HOCCUPAN
  1CY OF UNITS AS RELATED TO DESIGN CAPACITY)
   WRITE( 6,74)
74 FORMAT(1H0,63X,60HVACANT   GEAR   BELOW   WITHIN    0-25    25-75    OVE
  1R 75    TOTAL)
   WRITE( 6,76)
76 FORMAT(1H ,71X,42HONLY  LIMITS LIMITS  ABOVE   ABOVE    ABOVE)
80 NK=KIND1(KIND)
   SNO=FLOAT(SITE/10)
   WRITE( 6,82)(NAME(I),I=1,6),SNO
82 FORMAT(1H0,1X,6A6,3X,F9.1)
   WRITE(6,83)(KIND2(NK,J),J=1,4),(KTECH(TECH,K),K=1,2)
83 FORMAT(1H ,1X,3A6,A3,2A6)
   WRITE( 6,84)(WFAC1(I),I=1,7),FACGRP
84 FORMAT(1H0,25X,36HUNITS OCCUPIED AVE. WEEKDAY      1215, F6.1,F7.1,
  1F6.1,3F8.1,2F10.1)
   WRITE( 6,86)(WPOC1(I),I=1,7)
86 FORMAT(1H ,25X,36HPERCENT OCCUPIED                         F6.1,F7.1,F6
  1.1,3F8.1,F10.1)
   WRITE( 6,88)(WFAC2(I),I=1,7)
88 FORMAT(1H ,25X,36H                                   1815,F6.1,F7.1,F
  16.1,3F8.1,F10.1)
   WRITE( 6,86)(WPOC2(I),I=1,7)
   WRITE( 6,90)(HFAC1(I),I=1,7),FACGRP
90 FORMAT(1H0,25X,36HUNITS OCCUPIED AVE.SAT/SUN/HOL  1215,F6.1,F7.1,F
     16.1,3F8.1,2F10.1)
      WRITE( 6,86)(HPOC1(I),I=1,7)
      WRITE( 6,88)(HFAC2(I),I=1,7)
      WRITE( 6,86)(HPOC2(I),I=1,7)
      NOSITE=NOSITE+1
      IF(NOSITE.EQ.2) WRITE( 6,94)
   94 FORMAT(///70H0*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR THE ENT
     1IRE SAMPLE SEASON)
      IF(NOSITE.EQ.2)NOSITE=0
      NWD=0
      NHD=0
      DO 92 I=1,7
      WFAC1(I)=0
      WFAC2(I)=0
      HFAC1(I)=0
      HFAC2(I)=0
   92 CONTINUE
      GO TO 8
  500 STOP
      END
```

Appendix 2c

Listing of Program USPAT

```
PROGRAM USPAT
      DIMENSION NAME(7),NOPERS(12,14),CAL(46),FORST1(200),FORST2(200,4),
     1DISTR1(900),DISTR2(900,4),KIND1(999),KIND2(60,6)
      DIMENSION KIND4(60),KTECH(2,2)
     2   ,WPERS(13),HPERS(13),WPCAP(13),HPCAP(13),TMOFDA(12),CARS(10,18)
      DIMENSION FAC1(7),FAC2(7),
      INTEGER CAL,FOREST,DISTRT,REG,SITE,SET,TECH,DATE,FORST1,FORST2,
     1FORST3,DISTR1,DISTR2,DISTR3,FSUB,DSUB
      REAL NOPERS,NORODS,NWD,NHD,
      DATA TMOFDA(1)/6H 0915 /
      DATA TMOFDA(2)/6H 1015 /
      DATA TMOFDA(3)/6H 1115 /
      DATA TMOFDA(4)/6H 1215 /
      DATA TMOFDA(5)/6H 1315 /
      DATA TMOFDA(6)/6H 1415 /
      DATA TMOFDA(7)/6H 1515 /
      DATA TMOFDA(8)/6H 1615 /
      DATA TMOFDA(10)/6H 1815 /
      DATA TMOFDA(11)/6H 1915 /
      DATA TMOFDA(12)/6H 2015 /
      DATA TMOFDA(9)/6H 1715 /
      DATA (KTECH(1,I),I=1,2)/6HSINGLE,6H SITE /
      DATA (KTECH(2,I),I=1,2)/6HSITE C,6HOMPLEX/
      DO 2 I=1,38
      READ(5,1)CAL(I)
    1 FORMAT(I6)
    2 CONTINUE
      CALL LOADAK(KIND1,KIND2,KIND3,KIND4)
      CALL FOR(FORST1,FORST2,FORST3)
      CALL DIST(DISTR1,DISTR2,DISTR3)
      NWD=0
      NHD=0
      DO 3 I=1,13
      WPERS(I)=0
      HPERS(I)=0
      WPCAP(I)=0
      HPCAP(I)=0
      WAVIS=0
      HAVIS=0
      WTOVIS=0
      HTOVIS=0
    3 CONTINUE
    8 CONTINUE
    9 READ(5,10)REG,FOREST,DISTRT,SITE,KIND,SET,(NAME(I),I=1,7)
      IF(REG.EQ.99)GO TO 500
   10 FORMAT(2X,3I2,I4,I3,I2,6A6,A5)
      DO 20I=1,12
      READ(5,22)(NOPERS(I,J),J=1,14)
   20 CONTINUE
   22 FORMAT(17X,4F5.0,9F4.0,F3.0)
      READ(5,24)(FAC1(I),I=1,7),(FAC2(J),J=1,7),ONIT,DATE
   24 FORMAT(17X,14F3.0,F5.0,9X,I6)
      DO 30 I=1,10
      READ(5,32)(CARS(I,J),J=1,18)
   30 CONTINUE
   32 FORMAT(17X,6(F2.0,F4.0,F4.0))
      READ(5,34)SET,TECH,FACGRP,NORODS,SAXLE,PAOT
   34 FORMAT(15X,2I2,43X,F3.0,F1.0,F9.0,2X,F3.0)
   11 TECH=TECH-10
      DO 40 I=1,46
      IF(DATE.EQ.CAL(I)) GO TO 50
   40 CONTINUE
```

```
C      ***WEEKDAY***
       NWD=NWD+1.
       DO 42 I=1,12
       DO 42 J=2,13
       WPERS(I)=WPERS(I)+NOPERS(I,J)
    42 CONTINUE
       WPERS(13)=WPERS(13)+CNIT
       IF(SET.EQ.99)GO TO 60
       GO TO 8
C      ***HOL/WKEND***
    50 NHD=NHD+1.
       DO 52 I=1,12
       DO 52 J=2,13
       HPERS(I)=HPERS(I)+NOPERS(I,J)
    52 CONTINUE
       HPERS(13)=HPERS(13)+ONIT
       IF(SET.EQ.99)GO TO 60
       GO TO 8
    60 CONTINUE
       FMULT=1.
       DO 62 I=1,13
       IF(I.EQ.13) FMULT=12.
       WTOVIS=WTOVIS+WPERS(I)*FMULT
       HTOVIS=HTOVIS+HPERS(I)*FMULT
       WPERS(I)=WPERS(I)/NWD
       HPERS(I)=HPERS(I)/NHD
       WPCAP(I)=(WPERS(I)/PAOT)*100.
       HPCAP(I)=(HPERS(I)/PAOT)*100.
    62 CONTINUE
       WAVIS=WTOVIS/NWD
       HAVIS=HTOVIS/NHD
       WRITE( 6,70)
    70 FORMAT(1H1,33X,74HANALYSIS OF RECREATION USE DATA FOR SITES STATIS
      1TICALLY SAMPLED IN CY 1969)
       WRITE( 6,72)
    72 FORMAT(1HO,42X,51HAVERAGE NUMBER OF VISITORS RECORDED BY TIME OF D
      1AY*)
       NF=REG*100+FOREST
       CALL GETSUB (FORST1,FORST3,NF,FSUB,200)
       ND=NF*100+DISTRT
       CALL GETSUB(DISTR1,DISTR3,ND,DSUB,900)
       WRITE(6,74)REG,FOREST,(FORST2(FSUB,I),I=1,4),DISTRT,(DISTR2(DSUB,I
      1),I=1,4)
    74 FORMAT(1HO,22X,6HREGION,I3,9X,6HFOREST,I3,1X,3A6,A2,3X,8HDISTRICT,
      1I3,2X,3A6,A2)
       SNO=FLOAT(SITE)
       SNO=SNO/10.
       NK=KIND1(KIND)
       WRITE( 6,76)SNO,(NAME(I),I=1,6),(KIND2(NK,J),J=1,4),(KTECH(TECH,K)
      1,K=1,2),PAOT
    76 FORMAT(1HO,8HSITE NO ,F6.1,2X,9HSITE NAME,2X,6A6,    9HSITE KIND,1X
     1,3A6,A3,2X,2A6,2X,14HCAPACITY(PAOT),F6.1)
       WRITE( 6,78)
    78 FORMAT(1HO,30X,65HTIME OF            SITE USE IN TERMS OF NUMBER OF
      1 VISITORS PRESENT)
       WRITE( 6,80)
    80 FORMAT(1H ,32X,76HDAY      AVE.WEEKDAY      PRCNT CAPACITY      AVE.W
      1KEND/HOL.      PRCNT CAPACITY)
       DO 82 I=1,12
       WRITE( 6,83)TMOFDA(I),WPERS(I),WPCAP(I),HPERS(I),HPCAP(I)
    82 CONTINUE
    83 FORMAT(1HO,30X,A6,F14.1,F18.1,F18.1,F18.1)
```

Appendix 2c (continued)

```
      WRITE( 6,84)WPERS(13),WPCAP(13),HPERS(13),HPCAP(13)
   84 FORMAT(1H0,22X,17HOVERNIGHT CAMPERS,F11.1,F18.1,F18.1,F18.1)
      WRITE( 6,86)WAVIS,HAVIS
   86 FORMAT(1H0,    35HAVE. TOTAL VISITOR HRS/CALENDAR DAY,
     1                                                 F15.1,21X,F15.1)
      WRITE( 6,88)
   88 FORMAT(//////////69H0*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR
     1THE WHOLE SAMPLE SEASON)
      DO 90 I=1,13
      WPERS(I)=0
      HPERS(I)=0
      WPCAP(I)=0
      HPCAP(I)=0
   90 CONTINUE
      NWD=0
      NHD=0
      WAVIS=0
      HAVIS=0
      WTOVIS=0
      HTOVIS=0
      GO TO 8
  500 STOP
      END
```

Appendix 2d

Listing of Program ORGIN

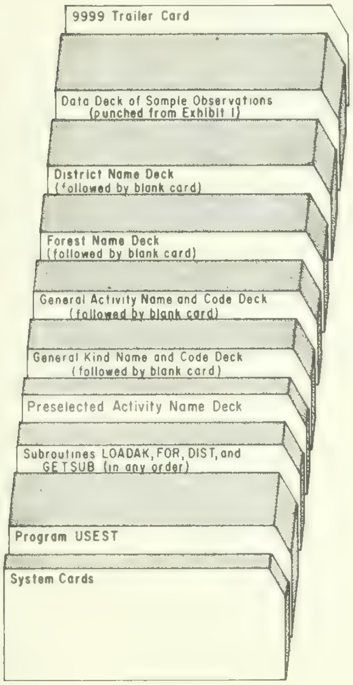
```
PROGRAM ORGIN
      DIMENSION NAME(7),NOPERS(12,14),CAL(38),FORST1(200),FORST2(200,4),
     1DISTR1(900),DISTR2(900,4),KIND1(999),KIND2(60,6)
      DIMENSION WORGIN(60,2),HORGIN(60,2),WTOT(2),HTOT(2),WAVE(60,2),
     1HAVE(60,2),WPCNT(60,2),HPCNT(60,2)
      DIMENSION STE(60,4)
      DIMENSION KIND4(60),KTECH(2,
     22),WPERS(13),HPERS(13),WPCAP(13),HPCAP(13),TMOFDA(12),CARS(10,18)
      DIMENSION FAC1(7),FAC2(7),
      INTEGER FOREST,DISTRT
      INTEGER REG,        SITE,SET,TECH,DATE,FORST1,FORST2,FORST3,DISTR
     11,DISTR2,DISTR3,FSUB,DSUB
      INTEGER CAL
      REAL NOPERS,NORODS,NWD,NHD,
      DATA TMOFDA(1)/6H 0915 /
      DATA TMOFDA(2)/6H 1015 /
      DATA TMOFDA(3)/6H 1115 /
      DATA TMOFDA(4)/6H 1215 /
      DATA TMOFDA(5)/6H 1315 /
      DATA TMOFDA(6)/6H 1415 /
      DATA TMOFDA(7)/6H 1515 /
      DATA TMOFDA(8)/6H 1615 /
      DATA TMOFDA(10)/6H 1815 /
      DATA TMOFDA(11)/6H 1915 /
      DATA TMOFDA(12)/6H 2015 /
      DATA TMOFDA(9)/6H 1715 /
      DATA (KTECH(1,I),I=1,2)/6HSINGLE,6H SITE /
      DATA (KTECH(2,I),I=1,2)/6HSITE C,6HOMPLEX/
      DO 2 I=1,38
      READ(5,1)CAL(I)
    1 FORMAT(I6)
    2 CONTINUE
      DO 6 I=1,60
      READ(5,5) NO,(STE(I,J),J=1,4)
    5 FORMAT(I2,3A6,A2)
      IF(NO.EQ.0) GO TO 7
    6 CONTINUE
    7 CONTINUE
      CALL LOADAK(KIND1,KIND2,KIND3,KIND4)
      CALL FOR(FORST1,FORST2,FORST3)
      CALL DIST(DISTR1,DISTR2,DISTR3)
      NWD=0
      NHD=0
      DO 3 I=1,13
      WPERS(I)=0
      HPERS(I)=0
      WPCAP(I)=0
      HPCAP(I)=0
      WAVIS=0
      HAVIS=0
      WTOVIS=0
      HTOVIS=0
    3 CONTINUE
    8 CONTINUE
    9 READ(5,10)REG,FOREST,DISTRT,SITE,KIND,SET,(NAME(I),I=1,7)
      IF(REG.EQ.99) GO TO 500
   10 FORMAT(2X,3I2,I4,I3,I2,6A6,A5)
      DO 20I=1,12
      READ(5,22)(NOPERS(I,J),J=1,14)
   20 CONTINUE
   22 FORMAT(17X,4F5.0,9F4.0,F3.0)
      READ(5,24)(FAC1(I),I=1,7),(FAC2(J),J=1,7),ONIT,DATE
```

Appendix 2d (continued)

```
   24 FORMAT(17X,14F3.0,F5.0,9X,I6)
      DO 30 I=1,10
      READ(5,32)(CARS(I,J),J=1,18)
   30 CONTINUE
   32 FORMAT(17X,6(F2.0,F4.0,F4.0))
      READ(5,34)SET,TECH,FACGRP,NORODS,SAXLE,PAOT
   34 FORMAT(15X,2I2,43X,F3.0,F1.0,F9.0,2X,F3.0)
   11 TECH=TECH-10
      DO 40 I=1,38
      IF(DATE.EQ.CAL(I)) GO TO 50
   40 CONTINUE
C     ***WEEKDAY***
      NWD=NWD+1.
      DO 44 I=1,10
      DO 44 J=1,16,3
      IF(CARS(I,J).EQ.0.) GO TO 44
      INDEX=CARS(I,J)
      DO 42 L=1,2
      JL=J+L
      WORGIN (INDEX,L)=WORGIN(INDEX,L)+CARS(I,JL)
   42 CONTINUE
   44 CONTINUE
      IF(SET.EQ.99)GO TO 60
      GO TO 8
   50 NHD=NHD+1.
      DO 54 I=1,10
      DO 54 J=1,16,3
      IF(CARS(I,J).EQ.0.) GO TO 54
      INDEX=CARS(I,J)
      DO 52 L=1,2
      JL=J+L
      HORGIN(INDEX,L)=HORGIN(INDEX,L)+CARS(I,JL)
   52 CONTINUE
   54 CONTINUE
      IF(SET.EQ.99)GO TO 60
      GO TO 8
   60 DO 64 I=1,53
      DO 64 J=1,2
      WAVE(I,J)=ABS(WORGIN(I,J)/NWD)
      HAVE(I,J)=ABS(HORGIN(I,J)/NHD)
      WTOT(J)=WTOT(J)+WAVE(I,J)
      HTOT(J)=HTOT(J)+HAVE(I,J)
   64 CONTINUE
      DO 68 I=1,53
      DO 68 J=1,2
      WPCNT(I,J)=ABS((WAVE(I,J)/WTOT(J))*100.)
      HPCNT(I,J)=ABS((HAVE(I,J)/HTOT(J))*100.)
   68 CONTINUE
      WRITE( 6,70)
   70 FORMAT(1H1,30X,74HANALYSIS OF RECREATION USE DATA FOR SITES STATIS
     1TICALLY SAMPLED IN CY 1969)
      WRITE( 6,72)
   72 FORMAT(1H0,54X,29HVEHICLES BY STATE OF ORIGIN *)
      NF=REG*100+FOREST
      ND=NF*100+DISTRT
      CALL GETSUB(FORST1,FORST3,NF,FSUB,200)
      CALL GETSUB(DISTR1,DISTR3,ND,DSUB,900)
      WRITE(6,74)REG,FOREST,(FORST2(FSUB,I),I=1,4),DISTRT,(DISTR2(DSUB,I
     1),I=1,4)
   74 FORMAT(1H0,22X,6HREGION,I3,9X,6HFOREST,I3,1X,3A6,A2,3X,8HDISTRICT,
     1I3,2X,3A6,A2)
      SNO=FLOAT(SITE)
      SNO=SNO/10.
      NK=KIND1(KIND)
      WRITE(6,76)SNO,(NAME(I),I=1,6),(KIND2(NK,J),J=1,4),(KTECH(TECH,K),
     1K=1,2),PAOT
   76 FORMAT(1H0,4X,8HSITE NO ,F6.1,2X,9HSITE NAME,1X,6A6,1X,9HSITE KIND
     1,1X,3A6,A3,1X,2A6,1X,14HCAPACITY(PAOT),F6.1)
      WRITE( 6,78)
   78 FORMAT(1H0,44X,8HWEEKDAYS,39X,15HWEEKEND/HOLIDAY)
      WRITE( 6,80)
   80 FORMAT(1H0,11X, 58HSTATE NAME      AVE.NO.CARS TALLIED        PER CE
     1NT ALL CARS,10X,19HAVE.NO.CARS TALLIED,7X,17HPER CENT ALL CARS)
      WRITE( 6,82)
   82 FORMAT(1H ,29X,94HON SAMPLE DAYS        TALLIED ON SAMPLE DAYS
     1    ON SAMPLE DAYS        TALLIED ON SAMPLE DAYS)
      WRITE( 6,84)
   84 FORMAT(1H ,29X,4H1215,5X,4H1815,11X,4H1215,6X,4H1815,13X,4H1215,5X
     1,4H1815,11X,4H1215,6X,4H1815)
      WRITE( 6,85)
   85 FORMAT(1H0)
      DO 86 I=1,53
      IF(WAVE(I,1).EQ.0..AND.WAVE(I,2).EQ.0..AND.HAVE(I,1).EQ.0..AND.HAV
     1E(I,2).EQ.0.) GO TO 86
      WRITE( 6,88)(STE(I,J),J=1,4),(WAVE(I,K),K=1,2),(WPCNT(I,L),L=1,2),
     1(HAVE(I,M),M=1,2),(HPCNT(I,N),N=1,2)
   86 CONTINUE
   88 FORMAT(1H ,6X,3A6,A2,F7.1,F9.1,F15.1,F10.1,F17.1,F9.1,F15.1,F10.1)
      WRITE( 6,90)(WTOT(J),J=1,2),(HTOT(K),K=1,2)
   90 FORMAT(1H0,7X,14HTOT ALL STATES,F12.1,F9.1,12X,3H100,7X,3H100,F17.
     11,F9.1,12X,3H100,7X,3H100)
      WRITE( 6,92)
   92 FORMAT(///////69H0*THIS ANALYSIS FOR SAMPLE DAYS ONLY, NOT FOR THE
     1 WHOLE SAMPLE SEASON)
      NHD=0
      NWD=0
      DO 94 I=1,53
      DO 94 J=1,2
      WORGIN(I,J)=0
      HORGIN(I,J)=0
      WAVE(I,J)=0
      HAVE(I,J)=0
      WTOT(J)=0
      HTOT(J)=0
      WPCNT(I,J)=0
      HPCNT(I,J)=0
   94 CONTINUE
      GO TO 8
  500 STOP
      END
```

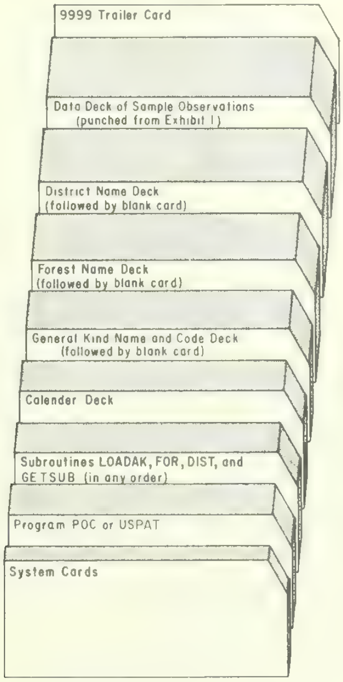
Appendix 3a

Deck Setup for Program USEST


9999 Trailer Card
Data Deck of Sample Observations (punched from Exhibit I)
District Name Deck (followed by blank card)
Forest Name Deck (followed by blank card)
General Activity Name and Code Deck (followed by blank card)
General Kind Name and Code Deck (followed by blank card)
Preselected Activity Name Deck
Subroutines LOADAK, FOR, DIST, and GETSUB (in any order)
Program USEST
System Cards

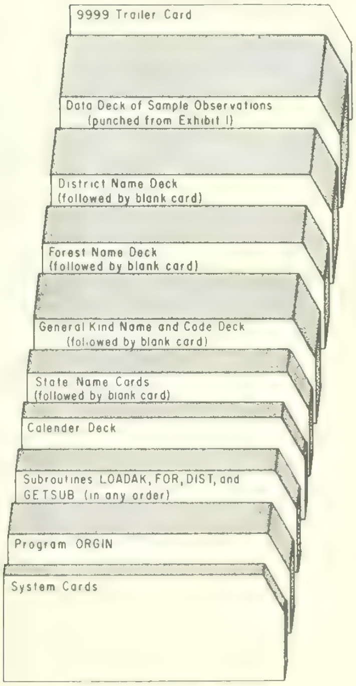
Appendix 3b

Deck Setup for Programs POC and USPAT


9999 Trailer Card
Data Deck of Sample Observations (punched from Exhibit I)
District Name Deck (followed by blank card)
Forest Name Deck (followed by blank card)
General Kind Name and Code Deck (followed by blank card)
Calender Deck
Subroutines LOADAK, FOR, DIST, and GETSUB (in any order)
Program POC or USPAT
System Cards

Appendix 3c

Deck Setup for Program ORGIN


9999 Trailer Card
Data Deck of Sample Observations (punched from Exhibit I)
District Name Deck (followed by blank card)
Forest Name Deck (followed by blank card)
General Kind Name and Code Deck (followed by blank card)
State Name Cards (followed by blank card)
Calender Deck
Subroutines LOADAK, FOR, DIST, and GETSUB (in any order)
Program ORGIN
System Cards

Appendix 4a

Listing of Subroutine LOADAK

```
      SUBROUTINE LOADAK(KODES,NAMES,NK,KLOC)
      DIMENSION KODES(999),NAMES(60,6),KLOC(60)
      DIMENSION NAME(6)
      DO 111 I=1,900
  111 KODES(I)=0
      NK=0
    1 READ(5,2)KOD,NAME
    2 FORMAT(I3,6A6)
      IF(KOD.EQ.0)RETURN
      NK=NK+1
      KODES(KOD)=NK
      KLOC(NK)=KOD
      DO 3 I=1,6
    3 NAMES(NK,I)=NAME(I)
      GO TO 1
      END
```

Appendix 4b

Listing of Subroutine FOR

```
      SUBROUTINE FOR(KODES,NAMES,NK)
      DIMENSION KODES(200),NAMES(200,4)
      DIMENSION NAME(4)
      DATA IB/6H      /
      DO 5 I=1,200
      DO 5 J=1,4
    5 NAMES(I,J)=IB
      CALL ERASE(KODES(1),KODES(200))
      NK=0
    1 READ(5,2)N1,N2,NAME
    2 FORMAT(2I2,20X,3A6,A3)
      IF(N1.EQ.0)RETURN
      NK=NK+1
      KODES(NK)=N1*100+N2
      DO 3 I=1,4
    3 NAMES(NK,I)=NAME(I)
      GO TO 1
      END
```

Appendix 4c

Listing of Subroutine DIST

```
      SUBROUTINE DIST(KODES,NAMES,NK)
      DIMENSION KODES(900),NAMES(900,4)
      DIMENSION NAME(4)
C     SUBROUTINE TO READ DISTRICT NAMES
      CALL ERASE(KODES(1),KODES(900))
      DATA IB/6H      /
      DO 5 I=1,900
      DO 5 J=1,4
    5 NAMES(I,J)=IB
      NK=0
    1 READ(5,2)N1,N2,N3,NAME
    2 FORMAT(3I2,54X,3A6,A2)
      IF(N1.EQ.0)RETURN
      NK=NK+1
      KODES(NK)=N1*10000+N2*100+N3
      DO 3 I=1,4
    3 NAMES(NK,I)=NAME(I)
      GO TO 1
      END
```

Appendix 4d

Listing of Subroutine GETSUB

```
      SUBROUTINE GETSUB(KODES,NK,NPOINT,NSUB,NDEM)
      DIMENSION KODES(NDEM)
C     SUBROUTINE TO GET SUBSCRIPT FOR FOREST,DISTRICT,COUNTY
      IF(KODES(NSUB).EQ.NPOINT)RETURN
      DO 1 I=1,NK
      NSUB=I
      IF(KODES(NSUB).EQ.NPOINT)RETURN
    1 CONTINUE
      NSUB=NK+1
      RETURN
      END
```

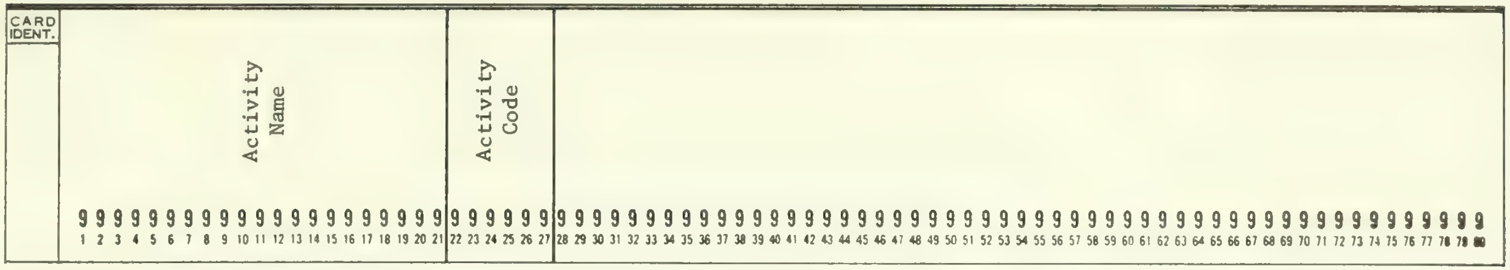
Appendix 5a

Formats for Data from Daily Sampling Record

CARD IDENT.		
1	Card No.	1 2
	Region No.	3 4
	Forest No.	5 6
	Dist. No.	7 8
	Principal Site No.	9 10 11 12
	Principal Site Kind	13 14 15
	Set No.	16 17
	Principal Site Name	18–58
	Station No. 1 24-hr. Diff.	59 60 61 62 63
	Station No. 2 24-hr. Diff.	64 65 66 67 68
	Station No. 3 24-hr. Diff.	69 70 71 72 73
	Station No. 4 24-hr. Diff.	74 75 76 77 78
		79 80
2-13		1 2
		3 4
		5 6
		7 8
		9 10 11 12
		13 14 15
		16 17
	Visits	18 19 20 21 22
	Picnicking	23 24 25 26 27
	Camping	28 29 30 31 32
	Team Sports	33 34 35 36 37
	Swimming & Bathing	38 39 40 41
	Water Sports	42 43 44 45
	Powerboat Launching	46 47 48 49
	Non-powerboat Launching	50 51 52 53
	Spectator Sports	54 55 56 57
	Exhibits, Talks	58 59 60 61
	Tours	62 63 64 65
	View Scenery	66 67 68 69
	Other Activity Use	70 71 72 73
	Other Activity Code	74 75 76
		77 78 79 80
14		1 2
		3 4
		5 6
		7 8
		9 10 11 12
		13 14 15
		16 17
	1215 Facility Groups Vacant	18 19 20
	1215 Gear Only	21 22 23
	1215 Below Lower Limit	24 25 26
	1215 Within Limits	27 28 29
	1215 25% Above	30 31 32
	1215 25-75% Above	33 34 35
	1215 +75% Above	36 37 38
	1815 Facility Groups Vacant	39 40 41
	1815 Gear Only	42 43 44
	1815 Below Lower Limit	45 46 47
	1815 Within Limits	48 49 50
	1815 25% Above	51 52 53
	1815 25-75% Above	54 55 56
	1815 +75% Above	57 58 59
	Number Overnight Campers	60 61 62 63 64
	Overnight Equip. in use: Auto	65 66 67
	Overnight Equip. in use: Tent	68 69 70
	Overnight Equip. in use: Trailer	71 72 73
	Date: Month	74 75
	Date: Day	76 77
	Date: Year	78 79
		80
15-24		1 2
		3 4
		5 6
		7 8
		9 10 11 12
		13 14 15
		16 17
	State No.	18 19
	Number Vehicles 1215	20 21 22 23
	Number Vehicles 1815	24 25 26 27
	State No.	28 29
	Number Vehicles 1215	30 31 32 33
	Number Vehicles 1815	34 35 36 37
	State No.	38 39
	Number Vehicles 1215	40 41 42 43
	Number Vehicles 1815	44 45 46 47
	State No.	48 49
	Number Vehicles 1215	50 51 52 53
	Number Vehicles 1815	54 55 56 57
	State No.	58 59
	Number Vehicles 1215	60 61 62 63
	Number Vehicles 1815	64 65 66 67
	State No.	68 69
	Number Vehicles 1215	70 71 72 73
	Number Vehicles 1815	74 75 76 77
		78 79 80
25		1 2
		3 4
		5 6
		7 8
		9 10 11 12
		13 14 15
		16 17
	Samp. Tech.	18 19
	Other Sites Included if a Complex: Number	20 21 22 23
	Other Sites Included if a Complex: Kind	24 25 26
	Other Sites Included if a Complex: Number	27 28 29 30
	Other Sites Included if a Complex: Kind	31 32 33
	Other Sites Included if a Complex: Number	34 35 36 37
	Other Sites Included if a Complex: Kind	38 39 40
	Other Sites Included if a Complex: Number	41 42 43 44
	Other Sites Included if a Complex: Kind	45 46 47
	Season Calibrated: Begin Month	48 49
	Season Calibrated: Begin Day	50 51
	Season Calibrated: Begin Year	52 53
	Season Calibrated: End Month	54 55
	Season Calibrated: End Day	56 57
	Season Calibrated: End Year	58 59
	Season Calibrated: Total Days	60 61 62
	Total Number Facility Groups	63 64 65
	Entrances	66
	Total Seasonal Metered Count	67 68 69 70 71 72 73 74 75
		76 77 78 79 80

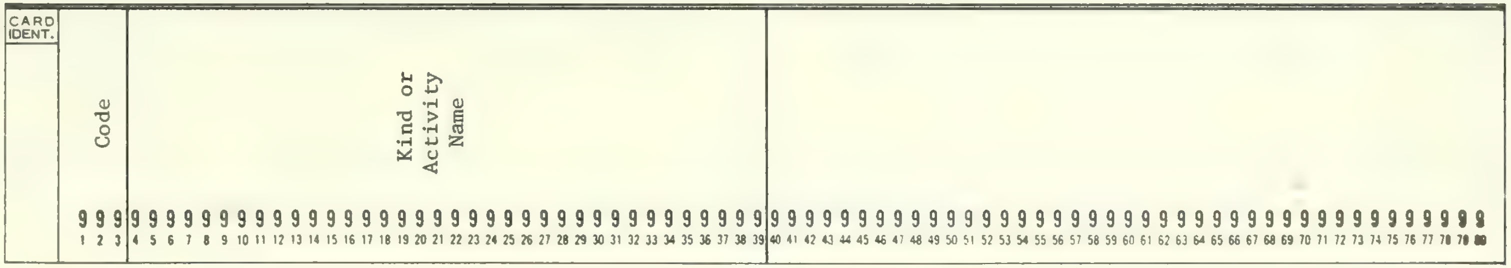
Appendix 5b

Format for Selected Activity Name and Code Deck



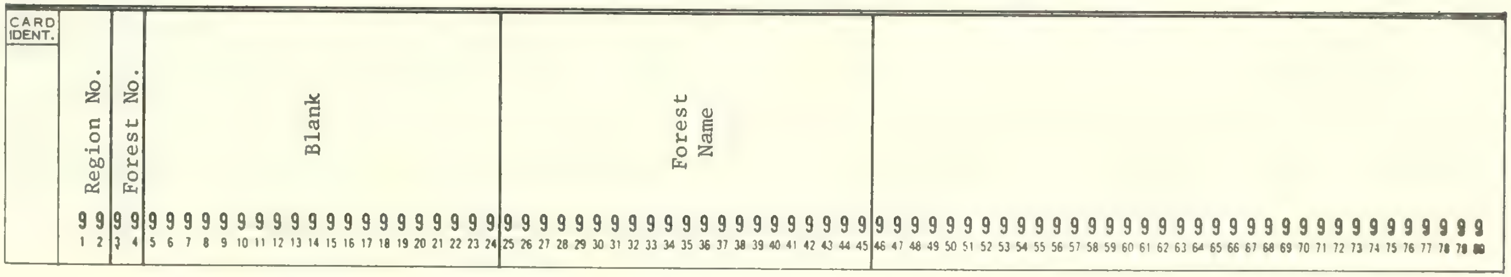
Appendix 5c

Format for General Activity and Kind Name Decks



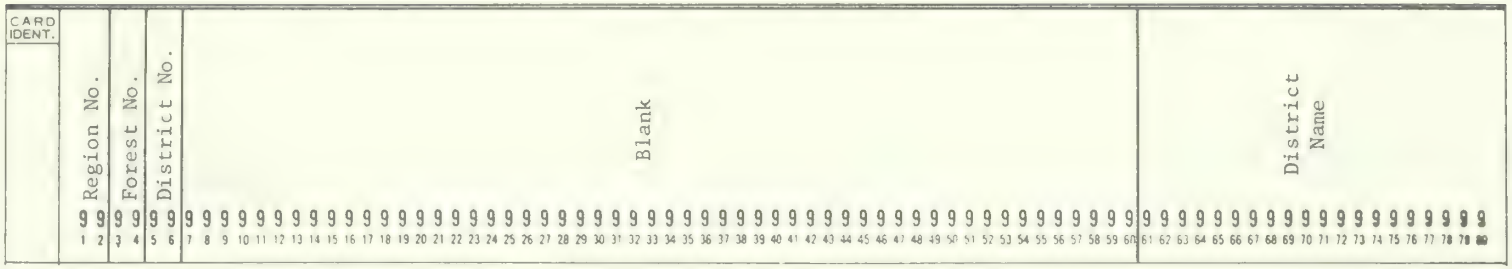
Appendix 5d

Format for Forest Name Deck



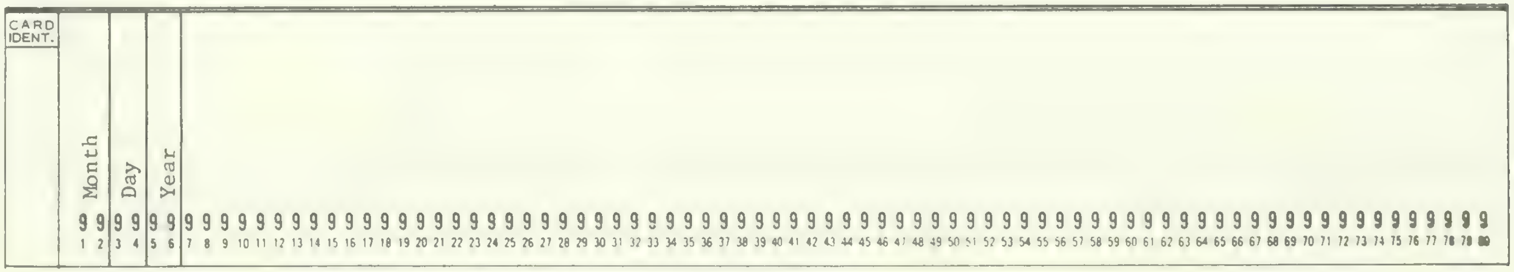
Appendix 5e

Format for District Name Deck



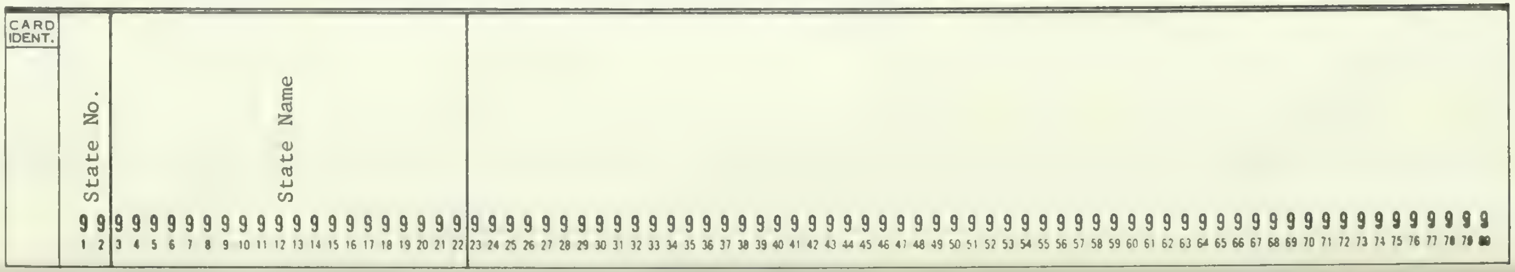
Appendix 5f

Format for Calendar Deck



Appendix 5g

Format for State Name Deck



Tyre, Gary L., and Welch, Gene R.
1972. Program manual for estimating use and related statistics on developed recreation sites. Southeast. For. Exp. Stn., USDA For. Serv. Gen. Tech. Rep. SE-1, 44 pp.

This manual includes documentation of four computer programs supporting subroutines for estimating use, visitor origin, patterns of use, and occupancy rates at developed recreation sites. The programs are written in Fortran IV and should be easily adapted to any computer arrangement having the capacity to compile this language.

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, SE 2

USDA Forest Service General Technical Report SE-2

Sand Pine Symposium

Proceedings

UNIVERSITY
22

December 5-7, 1972
PANAMA CITY BEACH, FLORIDA

USDA Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina
1973

Citation:

USDA Forest Service
1973. Sand pine symposium proceedings. Southeast. For. Exp. Stn. USDA For. Serv. Gen. Tech. Rep. SE-2, 253 pp.

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Proceedings

December 5–7, 1972
PANAMA CITY BEACH, FLORIDA

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First District of Florida

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FOREWORD

Sand pine, a species well suited to the excessively drained soils common to several million acres in the Southeast, was the subject of this well-attended 3-day meeting. Papers presented included a review of the literature plus results of current research related to this species. Subjects covered ranged from seeds and seedlings to final harvest and conversion of the tree into various products.

It was pointed out that sand pine is not the "ugly duckling" it is thought to be. Its wood properties, especially those of the Choctawhatchee variety of sand pine, are similar to those of loblolly pine and adequate to meet the needs of many wood products. Deterrents to its use are factors other than basic wood characteristics. These advantages and disadvantages should be a challenge to forest land managers. The potential of this species has been called to their attention. Perhaps we can expect sand pine to assume greater importance in the plans for the South's Third Forest.

A number of people contributed to this symposium. Of course, without the enthusiastic support of the experts invited to present papers, and the session moderators, there could be no symposium. Members of the Planning Committee who worked to make this meeting a success deserve recognition:

Russell M. Burns, Program Chairman
Southeastern Forest Experiment Station, USDA Forest Service

Edwin A. Hebb, Field Tour Chairman
Southeastern Forest Experiment Station, USDA Forest Service

Thomas G. Herndon, Local Arrangement Chairman
University of Florida

R. K. Strickland
University of Florida

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Florida Division of Forestry

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St. Joe Paper Company

William A. Hamilton
Southeastern Forest Experiment Station, USDA Forest Service

R. H. Brendemuehl, Chairman of Planning Committee
Southeastern Forest Experiment Station, USDA Forest Service

KEYNOTE ADDRESS

Honorable Robert L. F. Sikes
House of Representatives
Washington, D. C.
(1st District--Florida)

I am very pleased to participate in this important symposium on sand pines, a program which commemorates the 20th anniversary of the Chipola Experimental Forest. We who are jointly interested in west Florida and in forestry are very proud of this facility. I was privileged to participate in its establishment. I have continued to support it, and I am happy to note that there has been sound recent expansion.

Experimentation is a very important key to sound and profitable forestry programs. It is important to realize that there is a continuing requirement for forestry research in many areas. We still have problems of insect and disease control. We need growth studies and genetic studies toward stronger and more productive strains in trees. New harvesting practices and improved marketing methods obviously are due more consideration. All of these can be as important in our time as tree planting programs. We need to become aware of the problems of visual impact on forest visitors, of wildlife habitat, and of other management considerations. The public will become more and more sensitive about the way we manage forests. It is better to do our research and come up with the right answers than have it done for us and to have the wrong answers inflicted upon us.

In the sand pine program, it is essential that we be certain we are making contributions which justify the cost and the effort. Is our research effort moving in the right direction? Just what is it that we have learned about sand pines? Is sand pine truly an important economic asset? Some of the bloom may have departed from early hopes for sand pine. It is our business to learn whether its claim to fame is based on fact or fallacy.

That is what the Chipola Program is all about. There has been great enthusiasm for sand pine. Some of this undoubtedly has dimmed. Possibly, we expected too much. We need to know whether sand pine is truly a strong competitor for slash pine. Or, is it more realistically a substitute which is useful only in specific areas? I have seen exciting volunteer growths of sand pine in the deep sand forests of the Eglin Reservation, where, without help from man, sand pine has entered into competition and overcome scrub oaks. No other pine will do this.

This is truly a time for evaluation of sand pine. Where does it grow best? Under what circumstances is it economically a competitor? When and where is it preferable to slash pine or other species? In plain English, how can sand pines be used profitably in timber-growing programs?

Let me congratulate the participants who are here for the sand pine symposium. This is a very distinguished group. I am certain there has been no previous meeting which has gathered so much knowledge on this subject. We can all benefit from your contributions.

I realize that today I am preaching to the choir, but, where forestry is concerned, I am happy to do so. My work for forestry is not a new thing. It grew out of my boyhood days and my love for the outdoors. I feel at home where I can see growing trees and green shrubs and sparkling water. And I like to work for a better outdoors now and in the years ahead. The first large-scale tree planting project was begun in 1920. Legislation for systematic programs to control forest fires, for cooperative forest management, and for realistic research programs did not get underway until the late 1930's and the 1940's. Now, forestry practices are becoming the subject of a great deal of public interest.

I have been happy to note that a great, new, nationwide tree planting program is in progress. It is proposed to plant 75 million acres of trees in the environmental 70's. That means planting 60 billion trees.

A long time ago, one of America's greatest conservationists, Gifford Pinchot, said, "Conservation means wise use of the earth and its resources." That is still the name of the game for those who believe in strong forestry practices. But we have a selling job to do. This job includes tree planting. And it is where conservation starts.

I am not at all certain that there are enough people in the land who understand the significance of forestry and its economic importance to the Nation. There is a requirement to educate the public so they may better understand the blessings which come to us simply because one-third of the Nation's area is forest land; they must understand that forest land provides a continuous flow of renewable wood fiber for housing construction, packaging, and paper, in addition to scenic, wildlife habitat, watershed, and recreational values. We must ensure that more people realize that productivity of the forest is essential to the economy in employment and community development. The public needs to understand better the Nation's need for wood, the A B C's of renewable resource management on forest lands. There are so many who have little or no contact with or knowledge of forest problems who could be easy game for special-interest groups, including ecologists, who want to place their stamp on all programs, forestry and otherwise, even to the point of stopping sound utilization of forests.

Consideration for the ecology, which was virtually an unknown thing just a few years ago, has in many areas become a major item. In particular, it has affected proposals for water use and waterway improvements. It also affects forest use considerations. It very definitely slows approval of developmental projects and, in some instances, blocks them completely.

Ecology is a new and exciting "catch phrase." It is something very important; also, it can be overdone. Admittedly, it is serving to force attention on the need for correction of abuses, particularly abuses which are associated with pollution. What has been done toward control generally has been needed.

There must be a balance between what people want and what is practical. We cannot close down this country's business and industry just for the sake of ecology. But it is very certain that we cannot allow the growing and steadily worsening pollution of our earth to continue.

Let us talk about forestry legislation. A forestry legislative package which I was privileged to sponsor contains some very important provisions. Approximately 100 Congressmen were cosponsors. They are scattered the length and breadth of the land, and it is hard to find 100 Congressmen nowadays who have an understanding of forestry. P. L. 92-288 is a multi-purpose bill which is designed to update the Nation's forestry programs to meet present-day needs. The bill was drafted with the help of Federal and State forestry agencies and industry representatives, and it is now law.

As you well know, most existing forestry legislation had been placed on the statute books in the late 1940's and early 1950's, and some of this carries my name. The new law updates the Clarke-McNary Act for fire protection by doubling the annual authorization for Federal funds from $20 million to $40 million; it provides increased authorization for Cooperative Forest Management by increasing the authorization for Federal participation from $5 million to $20 million annually; and it provides a new program for urban and environmental forestry management with an annual authorization of $5 million.

There is also before the Congress a Forestry Incentives Bill. This bill has passed the Senate, largely because of the strong efforts of Senator Stennis, but it encountered very rough going in the House Committee, in part because of strong opposition of some Committee members to any type of subsidy program, and in part because of opposition by the Administration. A determined effort was made to get a bill reported and on the House Calendar. These efforts failed. I feel that we have made progress which can ensure a successful effort in the next Congress. We will not drop the fight until the job is done. There is very definitely a need for a forestry incentive program. It is intended to serve the forest landowner by encouraging sound forestry practices, just as agricultural programs have served the farmer by helping him take advantage of better farming practices.

Let us move slightly away from forestry. There are rural areas and small towns whose development has lagged, where too many young men and women must go elsewhere to make a living, where fertile fields and beautiful woodlands and streams are not fully utilized. One of the urgent needs in our Nation today is to reverse the flow of population from rural areas to city slums. Now Congress has enacted and the President has signed a rural development bill which can make the difference between today's rural problems and tomorrow's rural promise. The bill will stimulate small industry, including forest products, and community improvements.

There is a recreational potential for west Florida which has barely been tapped. People are learning about our beaches, and well that they should, for they are the most beautiful in the world. But their utilization can be doubled and redoubled without damage to ecological value if we let more people know about them. Beyond that is a hunting, fishing, camping, and boating potential which is virtually unknown beyond our own boundaries. The rivers, forests, bays, and inlets which we possess can be among the most attractive in the world. But it is not enough that they be pretty to look upon; they must offer advantages which bring people to enjoy their potential. This means a revitalized hunting and fishing program which really offers game and fish. It means clean, attractive, and safe camping areas. It means recreational facilities. These are available now only in a limited way. That is not good enough.

I am happy to call attention to the fact that the Federal Government has released funds to begin the water management study which my legislation made possible for west Florida. This is the project which will have a far-reaching impact on flood control, navigation, water supply, and waste water management. These factors will be studied, and proper guidance will be developed to control these problems. The study will also include general recreational facilities, enhancement and control of water quality, and conservation of fish, wildlife, and other resources for environmental purposes and for human relations. West Florida is an area that has been richly endowed with water resources. Few areas can boast as much. This fact will become increasingly important as the years pass. Water is becoming scarce in many areas now, and water supply is becoming more and more a problem in many parts of the Nation. We have water for human consumption, for recreational purposes, and for industrial use. If we manage it wisely, it will be one of our greatest assets.

The return of peace, for which there are very good prospects, emphasizes the need to focus on other activities, on the development of your resources, and on sound programs to ensure a healthy economy.

For years, America's defense industry has been a major factor in the economy. Now, there will inevitably be an increase in the demands for cuts in the U. S. Defense budgets. The pressures for more money for nondefense programs have been mounting even during the war. Percentage-wise, we have been spending less in recent years for defense and much more for other purposes in constant dollars. Defense budgets are lower now than they were even in 1962, which was a year of comparative peace.

There are always those who profess to see no dangers abroad and who will question the necessity for continued, large military expenditures. These people will add strength to the demands for more domestic spending. The Administration is not immune to these pressures, and already the Administration is seeking places to cut the defense dollars more. Among other proposals will be one on the closing of additional bases. No area is immune to this threat. The message should be very clear to us. It is important that our bases keep their best foot forward; that base personnel at all levels re-examine their sense of mission and their accomplishments and make certain that theirs is a base which is genuinely needed in the inventory. It is equally important that our local people show full support for the military bases in their area and a special degree of cooperation toward military personnel and their families. These are requirements in which we must all share.

We should seek the retention of a strong military presence for America because we live in a dangerous world. We have seen the effects of aggression by one small country of 20 million people in Indochina. For a generation, they have successfully defied efforts to bring peace to an entire area, and through some strange zeal, they have harnessed their people for the conquest of half of the area. This peace, which we so eagerly await, may leave them in possession of most of their ill-gotten gains because they probably will not move out of captured territory, regardless of agreements which may be reached.

If a pigmy among nations can create such havoc, we certainly cannot overlook the power which can be wielded by Russia and Red China in a world which now seeks to accommodate itself to threat rather than to resist threat. These countries embrace a philosophy of government which is alien to ours, and they seek world domination. Their entire national structure and all of their assets can be directed toward their aims. They have no labor problems, no minority problems, and only minimal demands for domestic improvements.

In other words, America still has formidable foes in the World--foes that respect only armed might. It would be extreme folly for this country to weaken itself to the point where our enemies know we dare not accept a confrontation on issues affecting world peace. For the foreseeable future, we must maintain a strong America.

There will be growing recognition for other considerations, hopefully worldwide. Of necessity, there must be such recognition here at home. There is a need now for west Florida to move as a single unit toward a better tomorrow. Regrettably, we have done this only in a very limited way. Each community, or each county, has in the main fought its own battles and sought its own objectives. That is not good enough in today's highly competitive world. We need to plan as one integral area for roads, waterways, airports, for industrial expansion, and for the redevelopment of the rural areas which have not held their own in progress. Always, there must be added concern for the ecology. We live in an age where the ecology is something of extreme importance. It is certain we cannot allow the growing and worsening pollution of our country to continue.

SAND PINE: DISTINGUISHING CHARACTERISTICS AND DISTRIBUTION

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Abstract.--Sand pine is endemic to the droughty, infertile soils of the sandhills where little other than scrub hardwoods, wiregrass, and scattered longleaf pines are able to survive and grow well. Other southern pines have been introduced into the sandhills, and several share features similar to those of sand pine. Morphological characteristics that differentiate sand pine from other southern pines and distinguishing features of the two recognized varieties of sand pine are discussed.

BACKGROUND

Sand pine (*Pinus clausa* (Chapm.) Vasey) is endemic to the sandhills. It seems appropriate, therefore, to first present some background information about the sandhills, i.e., to answer such questions as what and where the sandhills are and why they are in their present condition.

The sandhills are an important physiographic feature of the southeastern United States. They comprise about 30 percent of the land in Florida and extend in a narrow band through Georgia and South Carolina into North Carolina. South of St. Augustine and Ocala in peninsular Florida, they are used to grow citrus. North of the citrus zone, the soil and climate are well suited for melon production, but a rapid buildup of pathogens endemic in the soil makes cropping for more than 1 year in 7 a risky or expensive undertaking. Irrigated and fertilized, the soil will support a variety of other crops.

Sandhill soils developed from marine and fluvial deposits of sand which, either before or during deposition, were depleted of virtually all major and minor elements essential for plant growth. As the name *sandhills* implies, soils are mostly quartz sand ranging in depth from a few to more than 20 feet. Most contain only 1 to 2 percent organic matter in surface horizons and 10 percent or less silt plus clay in underlying profiles. Their relatively coarse texture and the paucity of organic and mineral exchange surfaces make them inherently droughty and infertile.

Moisture is relatively abundant and summertime temperatures are quite high throughout the sandhills. Average annual rainfall ranges from about 60 inches near the coast in northwest Florida to about 45 inches in South Carolina. Rainfall is fairly well-distributed throughout the year but, in general, is heaviest during June, July, and August. Despite the generous supply, water retention after only 1 day of drainage ranges from 5 to 8 percent on an ovendry-weight basis. Because of rapid to excessive internal soil drainage, most water percolates to depths below feeder roots. Surface soil temperatures of 135° F. are not uncommon, and they sometimes exceed 160° F. on exposed surfaces during the summer.

Longleaf pines (*Pinus palustris* Mill.) that occupied the sandhills during colonial times were worked for naval stores. The land was burned periodically to facilitate the operation and to improve forage for cattle and hogs. The pines were harvested progressively from north to south. Lumbermen finished harvesting most of the native longleaf pine in the early 1900's, but the burning continued. Some sandhill land was cleared and cropped to meet homestead requirements, but much was soon abandoned after the timber was harvested. Scrub hardwoods[1/] and wiregrass (*Aristida stricta* Michx.), both native to most sandhill soils, ultimately occupied the area, almost to the exclusion of other plants. Conditions remain essentially the same today.

1/ Principally turkey oak (*Quercus laevis* Walt.), bluejack oak (*Q. incana* Bartr.), common persimmon (*Diospyros virginiana* L.), and sand post oak (*Q. stellata* var. *margaretta* (Ashe) Sarg.).

Competition for available moisture and nutrients is intense. Roots of established woody and herbaceous plants fully occupy surface soils and rapidly deplete them. During periods of active plant growth, drought conditions can develop within days of a soaking rain. High temperature, abundant rainfall, and a coarsely textured soil with rapid internal drainage combine to oxidize litter and leach the nutritive products of its decomposition to depths plants are unable to tap. It is not surprising, therefore, that most introduced trees fail to survive an unaltered sandhill environment.

Contrary to popular impression, sandhill soils are not uniform. Sometimes the sand is underlain with one or more horizons of finely textured soil or with organic-coated sand. These impede internal soil drainage and, when they are within 12 to as much as 16 feet of the soil surface, may influence tree growth.[2/] More often than not, the horizons are at depths greater than 80 inches and so are not reflected in the present system of soil classification used in the United States. Therefore, the way a sandhill soil is classified does not necessarily suggest true soil depth or potential for tree growth. Occasionally, soil types are encountered when such horizons occur near the surface. When these occur, retention of soil moisture is improved and the soils are capable of supporting a broader spectrum of vegetation. Slash pine (Pinus elliottii Engelm.), loblolly pine (P. taeda L.), or even pond pine (P. serotina Michx.) and spruce pine (P. glabra Walt.) may survive and grow well in such areas. When these horizons are absent or below a depth where they can significantly affect the quantity of moisture available for tree growth, all but longleaf and the sand pines are growing offsite.

DISTINGUISHING CHARACTERISTICS OF SAND PINE

In the past, managers of sandhill land in Florida found longleaf pine difficult to regenerate and were reluctant to plant native, scrubby sand pine as long as other southern or exotic pines held promise of adaptability. In other Southern States, few were truly aware of the pine whose botanical range was confined almost solely to the State of Florida or of its potential for sandhill land. Most introduced pines failed to adapt to refractory conditions in the sandhills, but some of these plantings remain. The seven species other than sand pine most likely to be found are longleaf, slash, loblolly, shortleaf (P. echinata Mill.), pond, spruce, and Virginia (P. virginiana Mill.) pines.

The problem, therefore, is to distinguish sand pine from other southern pines and to differentiate between the two recognized varieties. Features recognizable in the field without aids have been used here to distinguish among the pines at any season of the year. Other features apparent only seasonally are listed as additional aids.

[2/] Hebb, E. A., and Burns, R. M. Slash pine productivity on Florida sandhills sites. (Manuscript in preparation.)

There would be little likelihood of confusing sand pine with other southern pines if all grew, or were planted, onsite. Sand pine is a tree for well- to excessively drained, infertile sand where little other than longleaf pine, scrub hardwoods, and wiregrass are able to survive and grow well.

Only rapid growth under sandhill conditions and flushes of growth during most seasons of the year serve to distinguish sand pine from the seven other pines. All other features are shared by one or more of these pines (table 1). However, if gross morphological characteristics possessed either by sand pines or by the other pines are used, differentiation between sand pine and each of the others is not difficult.

Sand pines have a reputation for poor form, rapid growth, and limbiness. The twisting trees have a tendency to retain their branches, cones, and needles. Branches or branch stubs may be found over the entire length of the bole. The condition gradually diminishes with age, especially in heavily stocked stands, but branch stubs are evident over a large portion of the bole even in some old trees. Sometimes cones are found embedded in branches or the bole as diameter growth envelops them (fig. 1). Needles normally are cast after the second growing season, but dry, gray remnants are occasionally found affixed to the bark of young trees after 5 or 6 years.

Needles range from 4 to 11 cm. (1.75 to 4.25 inches) and average 6.5 cm. (about 2.5 inches) in length. With the possible exception of spruce pine, needles of sand pine are finer and have a softer texture than those of other southern pines. Most authorities list the sand pines as having needles in fascicles of two. Although this is the most common number, fascicles containing three needles are frequently found near the terminus of growth flushes, especially on young, planted trees. On rare occasion, a fascicle with four needles may be found.

Cones vary somewhat in size in the recognized varieties of sand pine, but, in general, they average 6 to 9 cm. (2.5 to 3.5 inches) long. Buds are relatively small and reddish-brown in color.

Sand vs. Longleaf Pines

Both longleaf and sand pines are indigenous to sandhill soils, but here any similarity ends. Needle length alone is sufficient to differentiate between the two. However, the familiar form of seedlings and trees, color and size of buds, and size of cones might serve as well.

Table 1. --Features distinguishing sand pine from other southern pines in the sandhills of northern Florida

Pine	Needles/fascicle	Needle length	Characteristic bark[a]	Cone length	Cone morphology
	Number	Cm.		Cm.	
Sand	Mostly 2, sometimes 3, rarely 4	4-11	Conspicuous, yellow phellogen	6- 9	Stalked (mature may appear sessile)
Longleaf	3	20-45	Conspicuous, yellow phellogen	13-25	Stalked
Slash	2 and 3	15-30	Conspicuous, yellow phellogen	8-15	Stalked
Loblolly	3	12-25	Inconspicuous, gray phellogen	10-13	Sessile
Shortleaf	2 and 3	4-9	Conspicuous, yellow phellogen Gummy resin pits	4-8	Sessile (deciduous spines)
Pond	3 and 4	7-22	Inconspicuous, gray phellogen	5-7	Stalked (mature may appear sessile)
Spruce	2	4-10	Conspicuous, yellow phellogen Small plates resemble hardwood bark	5-10	Stalked
Virginia	2 (twisted)	2-5	Conspicuous, yellow phellogen	4-6	Stalked

[a] Phellogen is visible as the light-colored streaks in a cross-section of the bark.

Sand vs. Slash Pines

Needles and cones of slash pine are larger than those of sand pine. However, few slash pines older than 8 years retain many second-year needles on droughty, sandhill soils. For this reason, both needles and cones should be examined.

Sand vs. Loblolly and Pond Pines

Conspicuous, yellow phellogen serves to distinguish sand pine from loblolly and pond pines (fig. 2). Bark of sand pine and of most other southern pines contains conspicuous layers of ivory-white to yellow phellogen. Phellogen of the bark of loblolly and pond pines is an inconspicuous, slate-gray color (2).

Sand vs. Shortleaf Pines

Probably the best gross feature differentiating shortleaf pine from sand pine and from every other southern pine is the presence of small, isolated pits within the bark, many of which contain a gummy, resinous substance (4). They are most easily observed in the reddish-brown, corky phellem when large plates of shortleaf pine bark are removed (fig. 3). Once observed, evidence of the pits can be found on the surfaces of bark exfoliated with age. However, no gummy resin is present in pits on weathered surfaces. The bark of several other southern pines contains pits or shotholes of similar size, such as those made by bark beetles, but none are isolated nor are they as likely to contain gummy resin.

Sand vs. Virginia Pines

Lack of vigor, small cones, and short, twisted needles differentiate Virginia pine grown under sandhill conditions from sand pine. Virginia pine is in fact closely related to sand pine (6, 7). The two species share characteristics of branch and cone retention, and both have needles in fascicles of two. However, the botanical range of Virginia pine does not extend south of central Alabama and Georgia. It will not be encountered in the sandhills except in plantations, and here Virginia pine appears as a scrubby tree exhibiting lack of vigor and poor growth. Branches are not pruned naturally, and cones are retained on the tree for 5 to 15 years.

Sand vs. Spruce Pines

Aside from the rapid growth of sand pine, differences between sand and spruce pines in the sandhills are subtle. Young spruce pine has a light-gray bark as compared to the brownish-gray of sand pine bark. Older trees are more easily differentiated, not only by differences in bark coloration but also by the size and pattern of bark plates (fig. 4). Spruce pine has many bark fissures and small, tight plates that resemble hardwood bark, particularly that of some oaks and gums. The bark of sand pine has fewer fissures and larger and darker plates that cannot be confused with those of any hardwood.

Actually, spruce pine is a name occasionally ascribed to sand and Virginia pines (3), whereas in reality it is a separate species with many features resembling both. Spruce pines in the sandhills are characterized by needles 4 to 10 cm. (about 1.5 to 4.0 inches) long in fascicles of two stalked cones 5 to 10 cm. (about 2 to 4 inches) long that open when mature, and by a scrubby appearance and slow growth.

VARIETIES OF SAND PINE

Two varieties of sand pine are currently recognized. Before their value for reforesting the sandhills was exploited, they were all but separated geographically. Ocala sand pine (*Pinus clausa* var. *clausa* Ward) grew only in peninsular Florida, and Choctawhatchee sand pine (*P. clausa* var. *immuginata* Ward) grew principally in northwestern Florida. Now that both varieties have been planted extensively throughout their native sandhills, geographic location alone no longer is a reliable means of identification, except in natural stands of old trees.

The cone-opening feature reported by Little and Dorman (5) remains the most widely used means for differentiating Choctawhatchee sand pine (CSP) from Ocala sand pine (OSP). Cones of CSP open when mature, whereas those of OSP remain closed. Because young planted trees of both varieties are precocious, bear mature cones as early as plantation age 5, and retain their cones for many years, this one feature usually can be used for identification year-round.

Although reasonably reliable, cone-opening characteristics are not infallible for differentiating CSP from OSP. Both open and closed cones may be found on the same tree. Diseased, injured, or wet CSP cones remain closed or close temporarily. Some OSP cones open naturally when the resinous adhesive that seals them softens. The 125° F. temperature required for OSP cones to open (1) may come from direct sunlight or result from the combined effect of direct and reflected sunlight. For this reason, open OSP cones are found more frequently on exposed surfaces of upper crowns in dense stands and on lower branches in comparatively sparse stands. These atypical cones constitute a relatively small proportion of the total crop. The one exception occurs when humidity is high during or immediately following rain: at this time, virtually all CSP cones will be closed.

Stands of "open-coned" OSP have been found in peninsular Florida, principally in Pasco County and on and around the Withlacoochee State Forest in Hernando County. Virtually all of these cones open when mature. Presumably, these "open-coned" OSP are the CSP reported by Ward (8) in northwestern Marion County and in a few scattered locations elsewhere on the peninsula. Examination of the pines in Pasco and Hernando Counties showed that they possess some gross and microscopic features common to both CSP and OSP. To date, no taxonomic status has been assigned to the "open-coned" OSP. However, to differentiate these pines from CSP and OSP, local foresters refer to them as Withlacoochee sand pine (WSP).

Another group of OSP exists, differentiated from typical OSP and WSP by the proportion of mature cones that open. As many as one-half of these cones open without regard to their position in the crown or exposure to the sun. Several large groups of these OSP have been observed in Volusia and Flagler Counties. Others of this kind may exist elsewhere on the peninsula.

Coastal portions of Gulf and Franklin Counties in northwestern Florida contain stands of sand pine that are geographically isolated from contiguous regions of CSP and OSP. Although an open-cone variety predominates and is presumed to be CSP, a few small groves of sand pines with closed cones can be found between East Bay and Ochlockonee Bay. As yet, no definitive work has been done to identify the sand pines of this area.

Seasonal Difference Between CSP and OSP

Incidence of winter growth flushes, color of foliage of dormant seedlings, and the period during which staminate flowers shed their pollen can also be used to differentiate CSP from OSP. The paper "Temperature effects on growth, assimilation, and bud development of sand pine" will elaborate upon flushes of winter growth. Suffice it to say here that OSP flushes more readily than CSP.

Color differences between seedling foliage of CSP and OSP are almost undetectible during summer months. Although CSP may have a slightly darker hue, needles of both varieties are yellow-green. Cold winter weather brings out color differences (fig. 5). Yellow-green OSP becomes darker green but remains essentially the same color. In contrast, foliage of CSP seedlings changes first to blue-green and then, after a mid- or late-winter cold snap, to blue-green tinged with purple-red.

Time of ripening of staminate flowers, as evidenced by pollen release, is probably one of the most reliable phenological events distinguishing CSP from OSP. Five years of records from throughout the State show that, although mediated somewhat by weather and climate, time of pollen release is predictable within a comparatively short time span. CSP, for example, occurs naturally only in northwestern Florida, essentially within 1 degree of latitude. Pollen dissemination may start as early as the last week in December and end as late as the second week in March. However, the event most frequently occurs from late January through the end of February. OSP, in contrast, grows between latitudes 26° and 30° North, throughout most of the peninsula. At the southern extreme of its range, OSP may start shedding pollen as early as mid-November, whereas it may start a month or more later in northern Florida. In the sandhills of north Florida, OSP generally sheds its pollen from the last weeks of December through mid-January. Little, if any, overlap exists in the periods during which the two varieties disseminate pollen.

SUMMARY

Sand pine can be differentiated from other southern pines in the sandhills of northern Florida by one or more easily discernible characteristics of the needles, cones, or bark. The most significant of these, for year-round use, are listed in table 1.

The most widely used feature in distinguishing Choctawhatchee sand pine from Ocala sand pine is the open cones on CSP and the closed cones on OSP. Natural stands also can be identified by their geographic location. OSP is found in peninsular Florida, whereas CSP grows principally in northwest Florida. "Open-coned" OSP that may be confused with CSP is found in scattered locations on the peninsula. Such trees are known locally as Withlacoochee sand pine, but they do not have formal taxonomic status. During winter months, CSP seedlings have blue-green foliage that may have a purplish-red hue, whereas OSP needles remain yellow-green. OSP also flushes more readily than CSP when stimulated by warm weather during winter months. Probably the most reliable, easily recognized difference between the two varieties of sand pine is the period during which staminate flowers ripen. In north Florida, OSP sheds its pollen from mid-December through mid-January, whereas the flowers of CSP ripen from late January through the month of February.

LITERATURE CITED

1. Barnett, J. P., and McLemore, B. F. 1965. Cone and seed characteristics of sand pine. South. For. Exp. Stn., U. S. For. Serv. Res. Pap. SO-19, 13 pp.

2. DeVall, W. B. 1944. A bark character for the identification of certain Florida pines. Fla. Acad. Sci. Proc. 7: 101-103.

3. Fowells, H. A. 1965. Silvics of forest trees of the United States. USDA For. Serv. Agric. Handb. 271, 762 pp.

4. Harrar, E. S., and Harrar, J. G. 1946. Guide to southern trees. 712 pp. New York: McGraw-Hill Book Co., Inc.

5. Little, E. L., Jr., and Dorman, K. W. 1952. Geographic differences in cone-opening in sand pine. J. For. 50: 204-205.

6. __________ and Righter, F. I. 1965. Botanical descriptions of forty artificial pine hybrids. USDA For. Serv. Tech. Bull. 1345, 47 pp.

7. Morris, J. E. 1967. Racial variation in sand pine seedlings. Ninth South. Conf. For. Tree Improv. Proc. 1967: 132-136.

8. Ward, D. B. 1963. Contributions to the flora of Florida--2, Pinus (pinaceae). Castanea 28(1): 1-10.

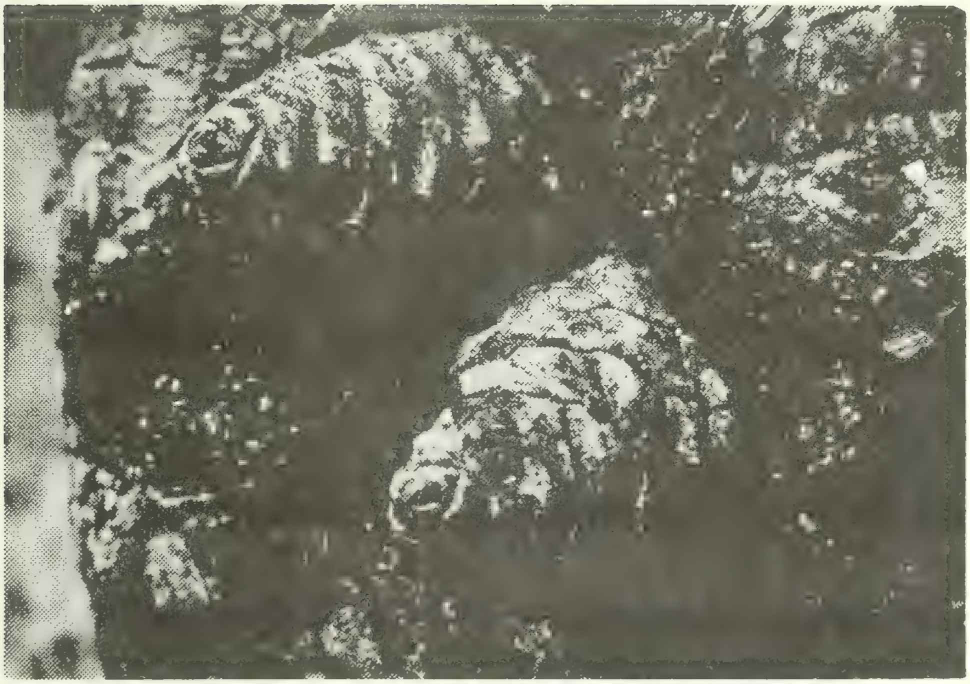

Figure 1.--Partially overgrown cones of Ocala sand pine. Only on rare occasions are cones completely engulfed by diameter growth of the tree.

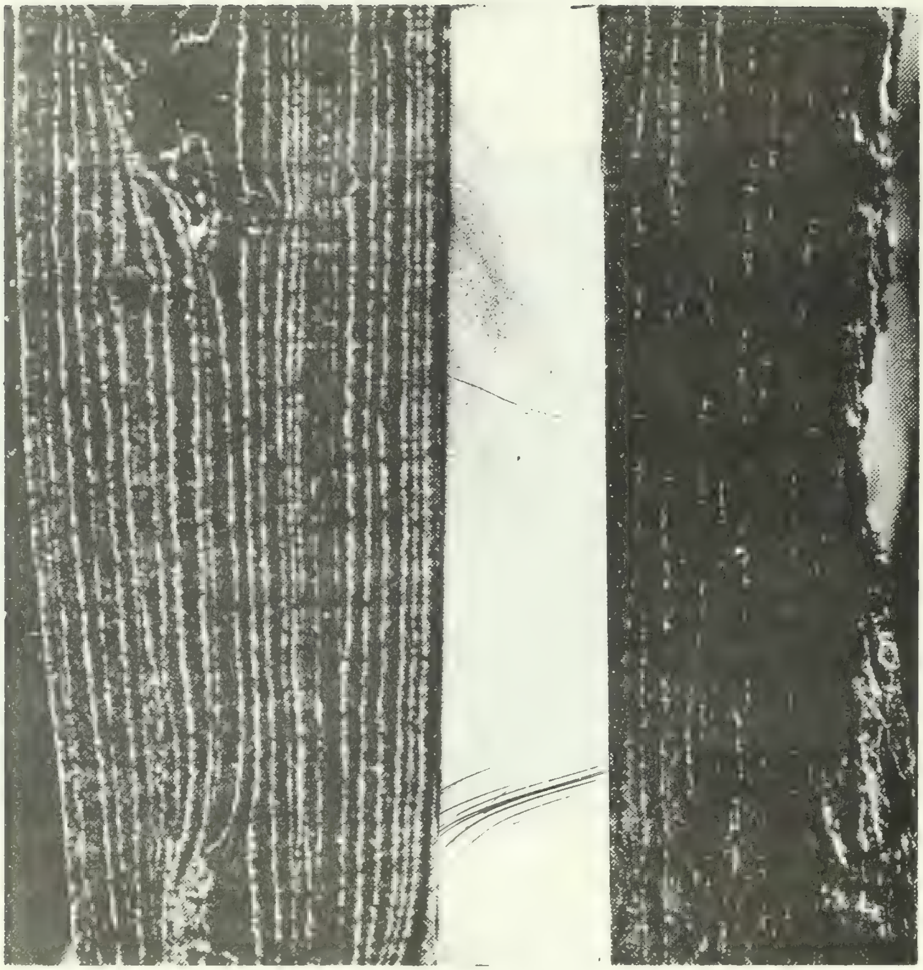

Figure 2.--The phellogen (streaks) of shortleaf pine bark (left), sand pine, and most other southern pines is more conspicuous than that of loblolly pine (right) or pond pine.

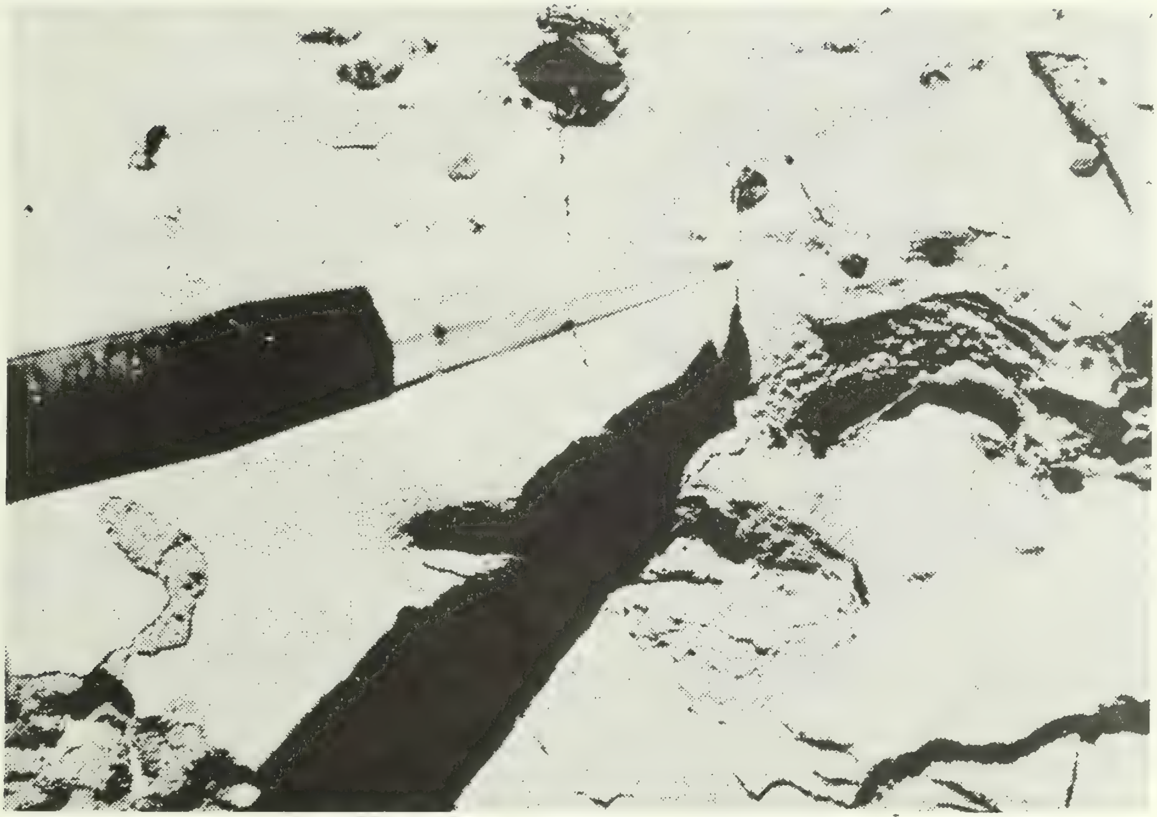

Figure 3. --The pencil shadow shows a strand of gummy substance extending from a small resin pit in shortleaf pine bark to the tip of the lead. Resin pits characterize the bark of this species.

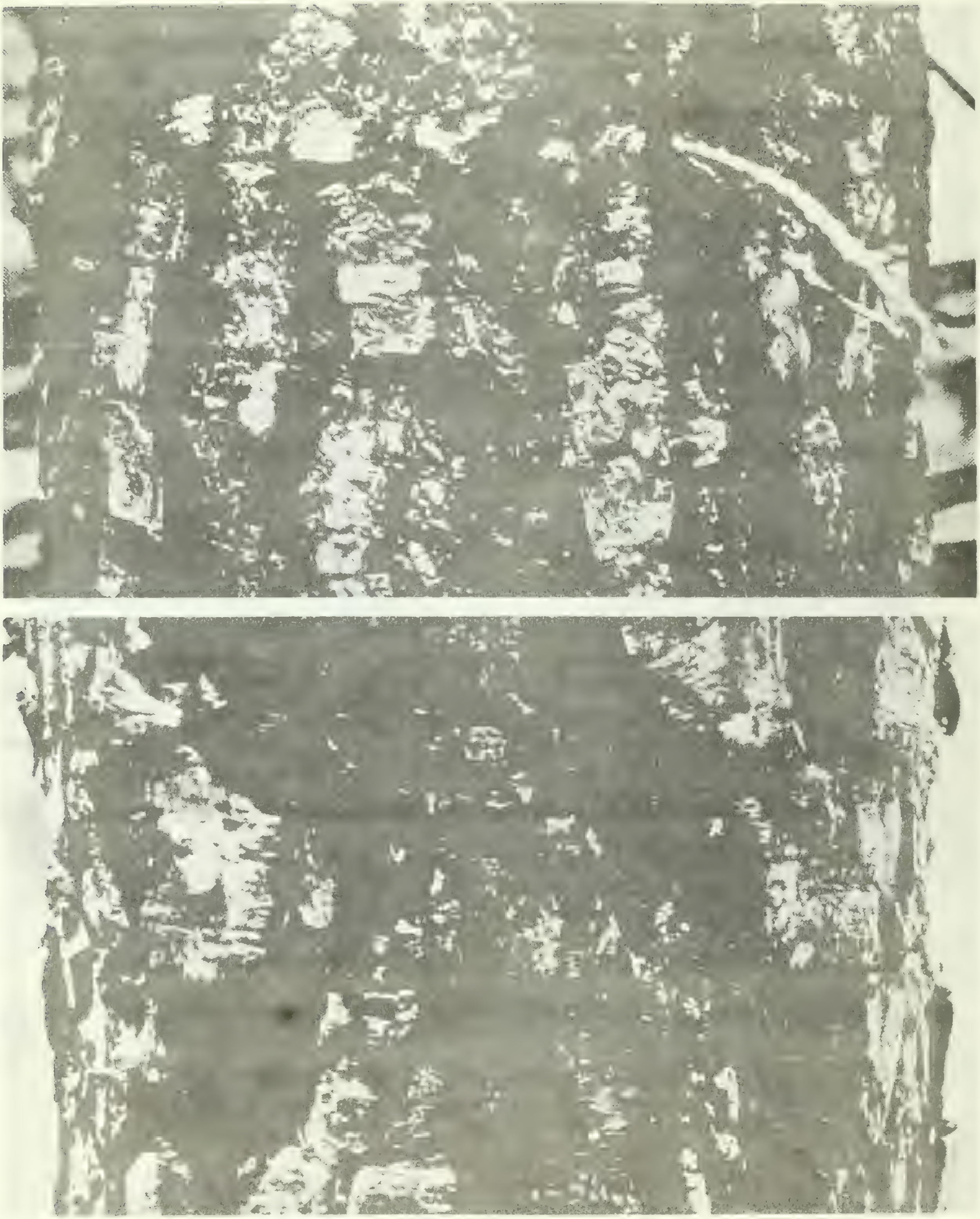

Figure 4.--The bark of spruce pine (top) with its small, light-gray plates resembles hardwood bark. The bark of sand pine (bottom) has larger and darker plates.

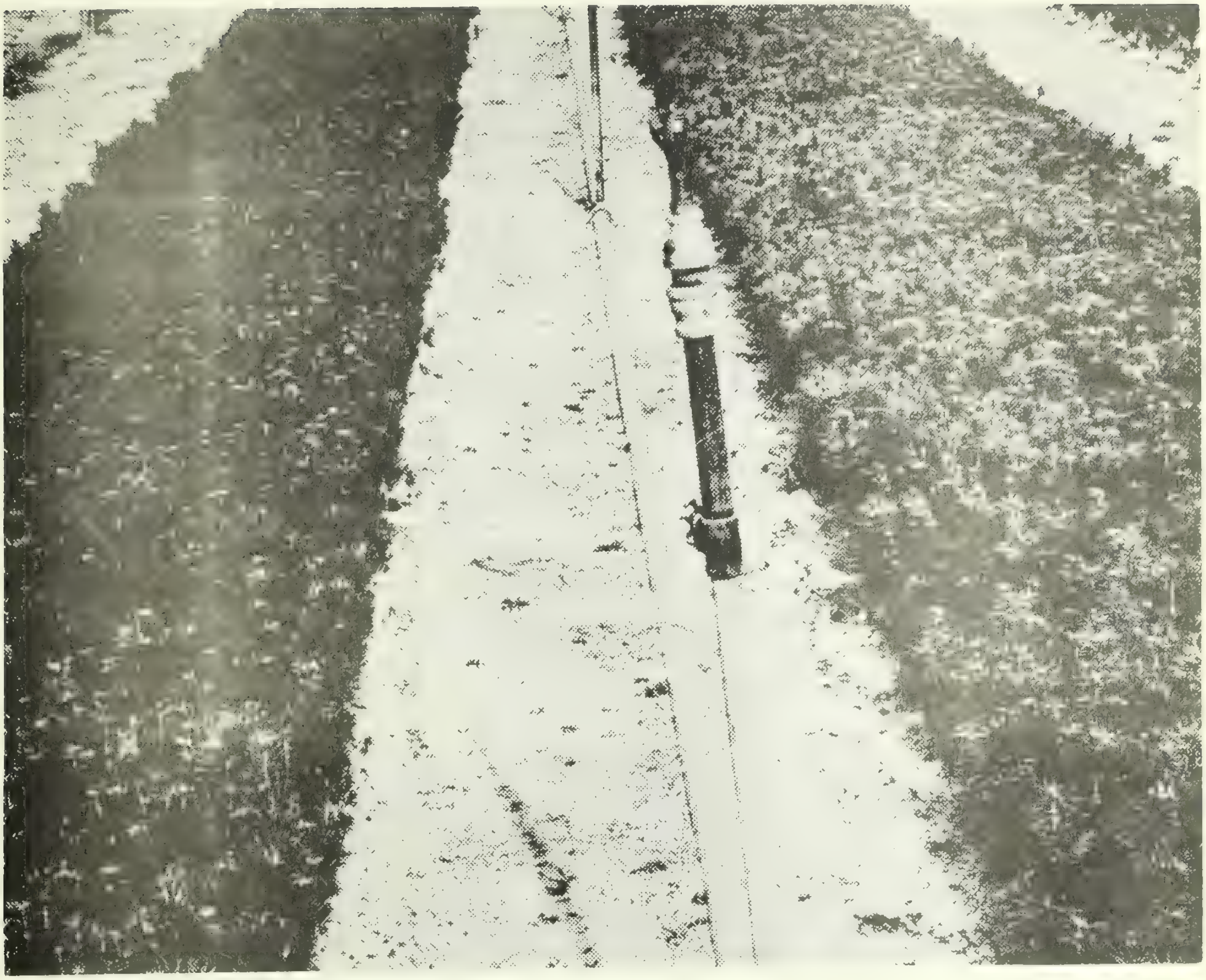

Figure 5.--CSP (left bed) and OSP (right bed). The darker hue of CSP is readily apparent even in this black and white photograph taken during the winter of 1971.

PROPERTIES, USES, AND POTENTIAL MARKET OF SAND PINE

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Abstract.--The anatomical features, chemical, mechanical, and physical properties, and wood quality characteristics of both varieties of sand pine are discussed in relation to end use. Current uses of sand pine are limited primarily to the pulp and paper industry, with a small volume being used for structural lumber. Investigations indicate that sand pine can be pulped under the same conditions as slash and longleaf pines with little sacrifice in pulp yield and that it can be readily mixed with these species without seriously affecting paper properties. There are future potential markets for sand pine in the veneer-plywood and particle-board industries.

INTRODUCTION

Sand pine (Pinus clausa (Chapm.) Vasey), one of the six minor species of yellow pines in the eastern United States, has received limited attention by wood technologists and other wood products researchers since it was first classified in 1880. The small, limby, generally crooked tree with a lacy, light-green crown presents a rather uninspiring sight, not only to people that are knowledgeable about trees but also to those who are not.

In addition to its generally poor appearance and small size, the fact that its range and total volume are relatively small are perhaps further reasons for the limited attention given it over the past 90 years. In the past, many people who saw sand pine for the first time asked, "What is it good for?" I am sure there are still many people asking the same question today. I hope to answer that question to some extent.

This paper will be limited to a review and interpretation of the literature available on the anatomical, mechanical, and physical properties, wood quality, paper-making characteristics, and the uses of the Ocala variety of sand pine (*Pinus clausa* var. *clausa* Ward) and the Choctawhatchee variety (*P. clausa* var. *immuginata* Ward). In the interest of brevity, these will be referred to as OSP and CSP.

WOOD PROPERTIES

Anatomical Characteristics

The anatomical characteristics of sand pine are identical to those of all the other species of yellow pines in the United States, making it impossible to distinguish it from other yellow pines on the basis of its anatomical features alone. The only true method of so distinguishing it is by examination of the fruit, flowers, and needles. The wood is tasteless and has a slight resinous odor typical of pines. The sapwood is white to buff, and the heartwood is a very light tan to a pinkish brown. In cross section, the annual rings are very distinct and readily visible to the naked eye because transition between earlywood (springwood) and latewood (summerwood) within an annual ring is abrupt. The resin canals are small and barely visible to the naked eye as fine, white dots on the end grain. In radial view, the resin canals appear as fine, light-brown, vertical and horizontal scratches. The wood rays are relatively small and inconspicuous in radial view. The pith is extremely small--generally less than 1/16 inch in diameter.

The wood is composed of six basic cell forms: (a) longitudinal tracheids, typical of gymnosperms, which make up the largest proportion of the woody tissue, (b) strand tracheids in limited quantity occurring along the vertical resin canals, (c) ray parenchyma, which makes up part of the ray tissue, (d) longitudinal parenchyma associated with vertical resin canals, (e) dentate ray tracheids, which make up the remainder of the rays, and (f) epithelial cells which line the vertical and horizontal intercellular spaces called resin ducts (10).

The bark of sand pine is similar in anatomical structure to that of the other species of yellow pines in the eastern United States (9). Like the wood, it is virtually impossible to distinguish from that of other yellow pines on the basis of bark anatomy. The inner bark (phloem) is made up primarily of longitudinal, thin-walled, sieve cells; albuminous ray cells; ray parenchyma; epithelial cells (only in the horizontal resin canals of fusiform rays); and dispersed, longitudinal parenchyma. The outer bark or periderm is made up of three general zones: a meristemic region of parenchymatous-type cells called the phellogen (cork cambium); an inner layer of parenchymatous tissue in various stages of expansion and varying wall thickness, called the phelloderm; and an outer layer, the phellum or corky portion of the bark made up primarily of thick-walled stone cells and thin-walled cork cells generally arranged in bands. All yellow pines contain the same types of periderm cells but considerable variation occurs in the arrangement of these cells. This is a feature that may have some diagnostic value, but it requires further research. In both varieties of sand pine, the thin-walled cork cells constantly form on the outer margin (9). The phellogen lines produced behind each laye of corky tissue are reported by DeVall (8) to be ivory white in sand pine as well as in five other yellow pines, and, although the lines are not in themselves sufficient for species identification, they are helpful in supplementing other means of recognizing the species.

Physical and Mechanical Properties

The physical and mechanical properties of sand pine are important from the standpoint of its use as a building or structural material. Information on these properties is limited to data developed by Markwardt and Wilso (13) in 1935 on five OSP trees collected in Marion County, Florida. The values based on this five-tree sample are shown in table 1, together with the properties of five other yellow pines that grow within the same geographical range. These species (loblolly, longleaf, slash, pond, and spruce pines) are listed for comparative purposes because sand pine lumber is mixed with that of the others and all are sold commercially under the same common name--southern yellow pine.

The data on physical properties in table 1 show that OSP has the lov est volumetric shrinkage (10.0 percent) and radial shrinkage (3.9 percent) o the species listed. Tangential shrinkage is also slightly lower (7.3 percent) than in all the species shown except pond pine. The lower shrinkage indicat that OSP is slightly more dimensionally stable than the other pine species. High dimensional stability is desirable in most wood products, especially in such items as paneling and siding.

Table 1 also shows the mean values of the various mechanical prop erties of sand pine and some associated pine species in the green condition and at 12 percent moisture content. These values, which were developed or

Table 1.--Physical and mechanical properties of sand pine (OSP) and other pine species within its range[a]

Pine species	Trees tested	Moisture content	Specific gravity at test	Wt. / cu. ft.	Shrinkage from green to ovendry, based on green dimension			Static bending					
					Volumetric	Radial	Tangential	Fiber stress at proportional limit	Modulus of-- Rupture	Modulus of-- Elasticity	Work to-- Proportional limit	Work to-- Maximum limit	Work to-- Total
	No.	Percent		Lb.	- - - Percent - - -			- Lb. /sq. in. -		1,000 lb. / sq. in.	- In. -lb. /cu. in. -		
Sand (OSP)	5	36	0.45	38	10.0	3.9	7.3	4,100	7,500	1,020	0.95	9.6	20.6
		12	.48	34				6,700	11,600	1,410	1.83	9.6	17.4
Loblolly	56	81	.47	53	12.3	4.8	7.4	4,100	7,300	1,410	.68	8.2	24.2
		12	.51	36				7,800	12,800	1,800	1.92	10.4	17.5
Longleaf	44	63	.54	55	12.2	5.1	7.5	5,200	8,700	1,600	.95	8.9	32.4
		12	.58	41				9,300	14,700	1,990	2.44	11.8	21.9
Pond	5	56	.50	49	11.2	5.1	7.1	4,500	7,400	1,280	.93	7.5	26.8
		12	.54	38				8,300	11,600	1,750	2.21	8.6	16.0
Slash	30	66	.56	58	12.2	5.5	7.8	5,100	8,900	1,580	1.02	9.5	30.6
		12	.61	43				9,800	15,900	2,060	2.76	12.6	20.8
Spruce[b]	35	(c/)	.41	--	--	--	--	2,900	6,000	1,000	.51	--	--
		12	.44	--	--	--	--	5,100	10,400	1,230	1.22	--	--

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[a] Data from Markwardt and Wilson (13) except where otherwise indicated.

[b] Data from Bendtsen (1).

[c] Green.

Table 1.--Physical and mechanical properties of sand pine (OSP) and other pine species within its range[a] (continued)

Pine species	Trees tested	Moisture content	Specific gravity at test	Wt./cu. ft.	Impact bending: Stress at proportional limit	Impact bending: Work at proportional limit	Impact bending: Height of drop causing complete failure (50-lb. hammer)	Compression parallel to grain: Stress at proportional limit	Compression parallel to grain: Maximum crushing strength	Compression perpendicular to grain, stress at proportional limit	Shear parallel to grain, maximum shearing strength	Tension perpendicular to grain, maximum tensile strength	Hardness, Load required to embed a 0.444-in. ball to 1/2 its diameter: End	Hardness, Load required to embed a 0.444-in. ball to 1/2 its diameter: Side
	No.	Percent		Lb.	Lb./sq. in.	Lb./cu. in.	In.	Lb./sq. in.	Lb./sq. in.	Lb./sq. in.	Lb./sq. in.	Lb./sq. in.	Lb.	Lb.
Sand (OSP)	5	36	0.45	38	9,800	4.6	25	2,670	3,440	560	1,140	380	460	480
		12	.48	34	12,400	5.4	19	3,900	6,920	1,030	1,100	300	950	730
Loblolly	56	81	.47	53	8,900	3.0	30	2,550	3,490	480	850	260	420	450
		12	.51	36	12,100	4.2	30	4,825	7,080	980	1,370	470	750	690
Longleaf	44	63	.54	55	10,100	3.2	35	3,430	4,300	590	1,040	330	550	590
		12	.58	41	15,400	6.1	34	6,150	8,440	1,190	1,500	470	920	870
Pond	5	56	.50	49	9,400	3.2	33	2,940	3,660	540	940	280	460	510
		12	.54	38	13,200	5.0	28	6,300	7,540	1,120	1,380	360	780	740
Slash	30	66	.56	58	10,800	3.9	36	3,040	4,340	680	1,000	400	600	630
		12	.61	43	15,800	8	36	6,280	9,100	1,390	1,730	570	1,080	1,010
Spruce[b]	35	([c])	.41	--	--	--	--	--	2,840	280	900	--	480	450
		12	.44	--	--	--	--	--	5,650	730	1,490	--	820	660

[a] Data from Markwardt and Wilson (13) except where otherwise indicated.

[b] Data from Bendtsen (1).

[c] Green.

small, clear test specimens, are indicative of the strength and structural properties of the wood and are the basic values used to compute working stresses for the design of wooden structures. Specific gravity is correlated with strength and, as can be seen in table 1, is quite variable among species. In order to put the more important strength properties on a comparative basis, ratios of strength to specific gravity were developed by taking the strength values in table 1 at 12 percent moisture content and dividing them by the specific gravity at the 12 percent level. The ratios of strength to specific gravity shown in table 2 indicate that sand pine is about equal to or better than the other species listed in breaking strength (modulus of rupture), crushing strength parallel to the grain, and compression perpendicular to the grain and that it can therefore be put to some of the same construction uses as the other yellow pines. It is, however, lower in stiffness (modulus of elasticity) than all species listed except spruce pine and is lowest in shear parallel to the grain. These characteristics limit the spans over which sand pine could be used. Because of its lower stiffness, it would have to be used over shorter spans; otherwise, it would exceed deflection limitations before reaching its load limitations.

Hardness is an indicator of ease of nailability as well as resistance to wear than the average of the other five yellow pines. OSP is higher in end-grain hardness and about equal in side hardness. It should, therefore, have about the same nailing and wearing characteristics as the other pines listed.

Chemical Composition

The chemical composition of the wood of the two varieties of sand pine is important in the pulping and chemical industries. Table 3 lists the basic chemical composition of both varieties, together with that of slash and longleaf pines--two species with which they are mixed in the manufacture of pulp. It appears from the limited analysis made in table 3 that both varieties of sand pine have a slightly lower lignin content than do longleaf and slash pines. Low lignin content is, of course, desirable because lignin has little use; thus, a low lignin content helps reduce the pulp industry's problems of disposal and pollution.

The holocellulose content is an indicator of the total non-lignin fraction of the wood. Table 3 shows that OSP has about 11 percent less holocellulose than do CSP and longleaf pine and about 3 percent more than slash pine.

Of primary significance are the yields of alpha-cellulose and pentosans. According to the analyses summarized in table 3, CSP has a higher alpha-cellulose content (8.6 percent more) and pentosans content (7.5 percent more) than OSP. This higher alpha-cellulose content of CSP would make it more desirable than OSP for the dissolving pulp industry in the manufacture

Table 2.--Ratios of strength to specific gravity for sand pine and several yellow pines within its range[a]

Pine species	Static bending		Maximum crushing strength parallel to grain	Compression perpendicular to grain, stress at proportional limit	Maximum shearing stress parallel to grain	Hardness	
	Modulus of rupture	Modulus of elasticity				End	Side
	Lb./sq. in.	1,000 lb./sq.in.	- - - - - - - - - - Lb./sq. in. - - - - - - - -			- - Lb. - -	
Sand (OSP)	24,200	2,900	14,400	2,150	2,290	1,980	1,520
Loblolly	25,100	3,500	13,900	1,960	2,690	1,470	1,350
Longleaf	25,300	3,400	14,600	2,050	2,590	1,590	1,500
Pond	21,500	3,200	14,000	2,070	2,560	1,440	1,370
Slash	26,100	3,400	14,900	2,280	2,840	1,770	1,660
Spruce	23,600	2,800	12,800	1,660	3,390	1,860	1,500

[a] Values in this table were computed by dividing the respective strength values at 12 percent moisture content in table 1 by their specific gravity at 12 percent moisture content.

Table 3.--Chemical composition of both varieties of sand pine and of longleaf and slash pines

Item	OSP[a]	CSP[b]	Longleaf pine[b]	Slash pine[c]
	Percent			
Lignin	27.2	28.4	29.2	28.5
Holocellulose	61.0	72.2	72.1	57.7
Alpha-cellulose	42.9	51.5	55.9	45.0
Pentosans	6.9	14.4	12.7	7.6
Alcohol-benzene	2.2	3.1	2.3	2.8
1 percent sodium hydroxide	11.8	11.4	11.0	10.8
Hot water	2.5	2.2	1.2	1.8
Ether	1.1			2.2
Ash		.4	.3	.3

[a] From Bray and Martin (2).

[b] From Martin (14).

[c] From USDA Forest Products Laboratory (21).

of rayon and nitrocellulose. The higher pentosans content makes it more desirable than OSP for the manufacture of furfural, a compound used to manufacture furan and phenolic resins. CSP is only 4.4 percent lower in alpha-cellulose and slightly higher in pentosans (1.7 percent) than longleaf pine. CSP has higher alpha-cellulose and pentosans contents than slash pine. OSP, on the other hand, has lower alpha-cellulose and pentosans contents than longleaf and slash pines. It appears from these data that CSP could be mixed with longleaf pine in the production of alpha-cellulose without seriously affecting the yield and that it would also contribute to a high yield of pentosans for furfural production.

WOOD QUALITY

Specific Gravity

Evaluation of the wood quality of sand pine has been centered around the development of information on wood specific gravity. This property has been given considerable attention because it has been found to be correlated with other wood properties and is relatively easy to determine.

Early determinations of the specific gravity of this species were made on a relatively small number of samples, from different parts of the stem as well as by different techniques. Because of these differences, considerable variation in the specific gravity of OSP was reported: Markwardt and Wilson (13) reported a specific gravity of 0.45, Bray and Martin (2) 0.46, McGovern and Keller (12) 0.51, Saucier and Taras (16) 0.48. CSP, which did not receive any attention until 1962, showed similar variations in specific gravity: Martin (14) reported 0.46 and Burns and Brendemuehl (3) 0.51.

The most comprehensive study of the specific gravity of sand pine was conducted by Clark and Taras (5) in 1969. As part of a wood density survey of the minor species of yellow pine in the eastern United States, both varieties of sand pine were sampled in 35 different locations over their entire ranges. Average specific gravity of increment cores was 0.439 for OSP and 0.485 for CSP. When increment cores were extracted with benzene and alcohol to remove the turpentine, gums, and resin acids (thereby leaving only the wood substance), the specific gravity of increment cores of OSP dropped to 0.407, a difference of 7.86 percent. In CSP, solvent extraction reduced specific gravity to 0.442, a reduction of 9.73 percent.

Estimates of average tree specific gravity of OSP and CSP as determined by this study are shown in table 4; these estimates are broken down by diameter classes and by Forest Survey Units in Florida and Alabama. Estimated tree specific gravity for all diameter classes averaged 0.419 for OSP and 0.482 for CSP. Examination of the data collected over the entire range of the two varieties indicated that there were no geographic trends from north to south or east to west, except for the major difference in specific

Table 4.--Specific gravity of OSP and CSP by diameter classes and by Forest Survey Units in Florida and Alabama[a]

OCALA SAND PINE

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Specific gravity of unextracted increment cores: Mean and standard error	Specific gravity of unextracted increment cores: Standard deviation	Estimated tree specific gravity,[b] mean and standard error	Approx. timber volume[c]
	No.	In.	No.				Million cu. ft.
Florida							
Northeast (1)	19	5.0- 8.9	254	0.438 (.005)	0.034	0.437 (.003)	42.4
		9.0-14.9	136	.441 (.006)	.043	.418 (.005)	18.0
		15.0+	10	.449 (.018)	.065	.379 (.017)	.9
Central (3)	6	5.0- 8.9	68	.425 (.008)	.048	.397 (.008)	13.0
		9.0-14.9	44	.452 (.008)	.041	.385 (.010)	5.1
		15.0+	11	.465 (.003)	.054	(d/)	.1
State total	25	5.0- 8.9	322	.435 (.004)	.035	.433 (.003)	55.4
		9.0-14.9	180	.444 (.005)	.041	.403 (.006)	23.1
		15.0+	21	.458 (.003)	.056	(d/)	1.0
Total all classes	25		523	.439 (.004)	.037	.419 (.004)	79.5

Table 4. --Specific gravity of OSP and CSP by diameter classes and by Forest Survey Units in Florida and Alabama[a] (continued)

CHOCTAWHATCHEE SAND PINE

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Specific gravity of unextracted increment cores: Mean and standard error	Specific gravity of unextracted increment cores: Standard deviation	Estimated tree specific gravity,[b] mean and standard error	Approx. timber volume[c]
	No.	In.	No.				Million cu. ft.
Alabama							
Southwest (1)	1	5.0- 8.9	9	.501(.019)	.057	.497(.012)	--
		9.0-14.9	11	.515(.017)	.056	.502(.011)	--
		15.0+	0	0	0	0	--
Florida							
Northwest (2)	9	5.0- 8.9	90	.480(.020)	.053	.480(.004)	8.8
		9.0-14.9	72	.484(.006)	.037	.478(.005)	1.1
		15.0+	11	.489(.009)	.057	.472(.012)	--
Total both states	10	5.0- 8.9	99	.482(.018)	.053	.482(.004)	8.8
		9.0-14.9	83	.488(.005)	.056	.481(.005)	1.1
		15.0+	11	.489(.009)	.057	.472(.012)	--
Total all classes	10		193	.485(.003)	.045	.482(.003)	9.9

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[a] Adapted from Clark and Taras (5).

[b] Estimates were made from the following equations:

OSP: Tree sp. gr. (Y) = 0.26222 + 0.56947 (sp. gr., 2 extracted cores) - 0.19747 (d.b.h./age).

CSP: Tree sp. gr. (Y) = 0.14879 + 0.78915 (sp. gr., 2 extracted cores) - 0.05552 (d.b.h./age).

[c] From Forest Survey data of the Southern and Southeastern Stations.

[d] The ratio of mean d.b.h. to age for the 15.0+ inch diameter class lies outside the range for which

gravity between CSP in western Florida and OSP in eastern Florida. One factor which may have contributed to some of the varietal differences in specific gravity could be the difference in age of the sample trees.

When these values for tree specific gravity are compared with those developed by the other investigators mentioned previously, it can readily be seen that the early investigators tended to overestimate the specific gravity of both varieties.

Values for tree specific gravity of the sand pine varieties are compared with those of the other yellow pines in the Southeast in the following tabulation:

Pine species or variety	Tree specific gravity	Source
Slash (var. densa)	0.58	Clark and Taras (6)
Slash	.53	USDA Forest Products Laboratory (22)
Longleaf	.53	USDA Forest Products Laboratory (22)
Table-Mountain	.49	Clark and Saucier (4)
CSP	.48	Clark and Taras (5)
Loblolly	.47	USDA Forest Products Laboratory (22)
Shortleaf	.47	USDA Forest Products Laboratory (22)
Pond	.47	Taras and Saucier (18)
Pitch	.47	Saucier and Clark (15)
Virginia	.45	Clark and Wahlgren (7)
Spruce	.43	Taras and Saucier (17)
OSP	.42	Clark and Taras (5)

These data show the tree specific gravity of CSP to be slightly higher than that of loblolly and shortleaf pines, two species that represent a major portion of yellow pine volume in the East. CSP is, however, lower in specific gravity than slash pine, its variety densa, longleaf pine, and Table-Mountain pine. The OSP variety, on the other hand, has the lowest specific gravity of all the yellow pines listed.

What does this difference in specific gravity mean in terms of utilization? From the pulping standpoint, both varieties will produce less pulp than slash and longleaf pines from the same volume of raw material. The difference in yields should not be as great for the CSP variety as it will be for the OSP variety. In the area of plywood and construction, it would be reasonable to assume that the CSP variety could be used for the same purposes as shortleaf and loblolly pines. Although the specific gravity of OSP is relatively low, this variety could still be used in plywood production. However, because of its low specific gravity, its use would be limited to the inner-ply portion of the plywood. In construction lumber, its lower specific gravity would indicate lower stiffness and its use would therefore be restricted to shorter spans than those used for other yellow pines of the same dimensions.

Tracheid Length

A wood property of considerable importance in papermaking is tracheid (or fiber) length because it is highly correlated with the tear, burst, and tensile strengths of paper. As can be seen in table 5, rather limited data are available regarding this property. In his book on the southern pines, Koch (11) shows on the basis of a survey of the literature that sand pine has an average fiber length of 3.5 mm. This is 0.5 mm. shorter than the length reported for the four major species of yellow pines (loblolly, slash, longleaf, and shortleaf). This small difference in fiber length is not a limiting factor in the manufacture of pulp and paper from sand pine.

Koch (11) developed data on fiber length from one tree of each variety. His data show that OSP has a higher average fiber length (4.4 mm.) than CSP (3.64 mm.). Because of the limited sample, these data should be considered as only indicative of fiber length.

The USDA Forest Products Laboratory (19) reported the average fiber length of sand pine to be 2.85 mm.--which appears to be rather low. This discrepancy has perhaps resulted because pulp and paper manufacturers generally report measurements made on all cellular elements and broken fibers rather than on the fibers alone.

Tracheid Dimension

Tracheid dimensions are properties of wood that are avoided by most researchers because of the difficulty, tediousness, and time consumption involved in gathering the data. Consequently, the information available on cell wall thickness and diameter is very limited. Such data are important in the pulp and paper field because they reflect the ease of collapsibility of the fiber as well as its flexibility, both of which play an important role in paper properties and characteristics.

Table 5. --Tracheid length for both varieties of sand pine

Pine species or variety	Tracheid length	Range SD	Trees sampled	Comments on samples	Source
	- - - - Mm.	- - - -	No.		
Sand	2.85	--	--	--	USDA Forest Products Laboratory (19)
OSP	4.40	0.76	1	Mean for one 58-yr.-old tree, range was 2.8 to 6.5 mm.	Koch (11)
CSP	3.64	.67	1	Mean for one 57-yr.-old tree, range was 2.2 to 5.1 mm.	Koch (11)
CSP	3.6	--	--	Range was 1.5 to 5.5 mm.	Buckeye Cellulose Corporation[a]

[a] Buckeye Cellulose Corporation. Sand pine properties and uses. Personal correspondence, April 20, 1972.

Single-wall thickness and tangential and radial diameters of earlywood and latewood cells are shown for both varieties of sand pine in table 6. The data in this table are limited to Koch's (11) observations made on one tree of each variety and should be considered as only weak indicators of the various parameters measured. On the basis of these data, radial and tangential wall thicknesses of the earlywood cells of both varieties are the same--about 3.7 microns. In latewood, the radial walls appear to be slightly thicker (1 to 2 microns more) than the tangential walls in both varieties. The latewood of OSP has slightly thicker cell walls (1 to 2 microns more) than CSP.

In the earlywood, radial diameter is larger by 2 to 4 microns than the tangential diameter in both varieties. In the latewood cells, the tangential diameter is 5 to 6 microns larger than the radial diameter. In both the earlywood and the latewood, CSP has cells of smaller diameter than OSP.

When the cell dimensions of both varieties are compared with those of slash and longleaf pines, it appears that the wall thickness of the earlywood of both varieties is about equal to that of longleaf pine and greater than that of slash pine. The cell wall thickness of the latewood of OSP is equal to that of slash and longleaf pines, but CSP has slightly thinner walls than the two major yellow pines. The diameters of the earlywood cells of both varieties are smaller (by 10 to 12 microns) than those of longleaf and slash pines.

In the latewood, slash and longleaf pines both have larger cell diameters than sand pine. In a study made by the Buckeye Cellulose Corporation,[1] wall thickness of CSP was reported to be 7.7 microns, which is slightly higher than that reported by Koch (11). Cell diameter, however, was reported as 34 microns, which is equivalent to that reported by Koch for the average of springwood and summerwood tracheids.

Heartwood and Sapwood

The amounts of heartwood and sapwood contained in a tree are important in wood preservation because they are directly related to wood durability and penetrability of preservatives. Large proportions of sapwood are desirable because of the ease of penetration of preservative into this type of tissue. Heartwood is virtually impenetrable but slightly more durable than sapwood.

A study of the percentage of heartwood and the depth of sapwood in both varieties of sand pine indicated that heartwood in trees of both varieties

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[1] Buckeye Cellulose Corporation. Sand pine properties and uses. Personal correspondence, April 20, 1972.

Table 6.--Tracheid dimensions for both varieties of sand pine and for longleaf and slash pines as based on single-tree samples[a]

Pine species or variety	Cells measured	Single-wall thickness				Cell diameter			
		Tangential	SD	Radial	SD	Tangential	SD	Radial	SD
	No.	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - Microns	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - -
				EARLYWOOD					
OSP	104	3.7	0.8	3.7	0.9	36.9	5.6	39.4	5.5
CSP	296	3.7	.9	3.6	.8	34.6	5.8	38.7	6.2
Longleaf	384	4.0	1.1	3.8	1.1	47.7	7.2	49.2	7.9
Slash	216	3.2	.3	3.2	.3	45.1	8.4	52.1	9.3
				LATEWOOD					
OSP	52	9.8	1.9	11.7	1.8	34.7	5.3	28.8	4.2
CSP	164	8.7	1.5	9.9	1.8	32.6	5.2	26.9	4.3
Longleaf	300	9.9	1.9	12.0	2.7	38.8	7.0	31.1	5.3
Slash	124	9.0	1.4	12.9	2.8	39.1	7.0	27.1	3.9
				ALL WOOD					
OSP	156	5.7	3.2	6.3	4.0	36.2	5.6	35.8	7.2
CSP	460	5.5	2.7	5.8	3.3	33.0	5.7	34.5	8.0
Longleaf	684	6.6	3.3	7.4	4.5	41.0	7.4	41.3	11.3
Slash	340	5.3	2.9	6.8	5.0	42.9	8.4	43.0	14.3

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[a] Data from Koch (11). OSP was 58 years old, 10.3 in. d.b.h., and 58.0 ft. high. CSP was 57 years old, 18.2 in. d.b.h., and 69.0 ft. high. Longleaf pine was 60 years old, 16.7 in. d.b.h., and 91.5 ft. high. Slash pine was 39 years old, 14.8 in. d.b.h., and 74.5 ft. high.

averages about 27 percent.[2] This study was conducted on 84 OSP and 50 CSP trees that ranged in age from 12 to 72 years and in d. b. h. from 5.1 to 17.1 inches. Prediction equations have been developed for estimating percentage of heartwood with either age or age and d. b. h. as independent variables; these equations are shown in table 7, together with equations for estimating depth of sapwood. According to the USDA Forest Products Laboratory (20), depth of sapwood in southern yellow pines ranges from 3 to 6 inches, especially in second-growth trees. Taras' unpublished study shows the average depth of sapwood to be 1.79 inches for OSP trees 42 years of age and 2.01 inches for CSP trees 44 years of age.

Percentage of Summerwood

Percentage of summerwood is an expression of the proportion of the denser, smaller-celled part of a growth ring. It is a property correlated with specific gravity and is sometimes used as a rough indicator of it. Growth rings vary considerably in this property from the pith to the bark within a tree and from the bottom of the tree to the top within a given growth sheath. Proportions of summerwood above 30 percent are generally associated with relatively high specific gravity. No information exists on the relative amount of summerwood contained within either variety of sand pine on a total-tree basis. In 1943, McGovern and Keller (12) indicated the summerwood on a small sample of OSP pulpwood to be 32.5 percent. In 1962, Martin (14) showed the summerwood of some CSP pulpwood to be 28 percent. The relative value of this particular property is difficult to assess.

PULP AND PAPER QUALITIES

Pulping Characteristics

Sand pine was first evaluated as a potential pulp and paper species in 1927 by Wells and Rue (23). Although their first tests were limited, they stated that, under the sulfite process, sand pine has uniform digestion qualities and yields pulp of very fair quality, capable of bleaching with reasonable quantities of chemical (10 to 20 percent), and suitable for wrapping and printing papers. Yields were between 25 and 35 percent. Sand pine was also found to reduce readily by the sulfate process and to produce unbleached pulp of fair strength, suitable for high-grade kraft wrapping papers and fiberboards. Yields were reported to be between 40 and 45 percent.

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[2] Taras, Michael A. 1972. (Unpublished data, Work Unit on Grade and Quality of Southern Timber, Southeast. For. Exp. Stn., For. Sci. Lab., Athens, Ga.)

Table 7.--Prediction equations for estimating the percentage of heartwood and the depth of sapwood in trees of both varieties of sand pine[a]

PERCENTAGE OF HEARTWOOD

	Average--							
Variety	Sample trees	Age	D.b.h.	Ht.	Correlation coefficient	Coefficient of determination	Regression equations	SE associated w/regression
	No.	Yr.	In.	Ft.				
OSP	84	42	8.7	51.3	0.685	0.470	$Y = 1.4191 + 0.6169 \text{ (age)}$	9.01
					.709	.504	$Y = -4.2017 + 0.5733 \text{ (age)} + 0.8545 \text{ (d.b.h.)}$	8.88
CSP	54	44	10.8	54.4	.685	.469	$Y = -5.9556 + 0.7616 \text{ (age)}$	7.67
					.756	.498	$Y = -6.9423 + 0.6435 \text{ (age)} + 0.5746 \text{ (d.b.h.)}$	7.68
Both	138	43	9.6	52.9	.681	.464	$Y = -0.2768 + 0.6474 \text{ (age)}$	8.56

Table 7.--Prediction equations for estimating the percentage of heartwood and the depth of sapwood in trees of both varieties of sand pine[a] (continued)

DEPTH OF SAPWOOD

Variety	Average-- Sample trees	Average-- Age	Average-- D.b.h.	Average-- Ht.	Correlation coefficient	Coefficient of determination	Regression equations	SE associated w/regression
	No.	Yr.	In.	Ft.				
OSP	84	42	8.7	51.3	.628	.395	$Y = 0.9352 + 3.5454\left(\frac{\text{d.b.h.}}{\text{age}}\right)$	.528
					.695	.483	$Y = 1.2871 + 0.1622\,(\text{d.b.h.}) - 0.0220\,(\text{age})$	.497
CSP	54	44	10.8	54.4	.792	.627	$Y = 0.5155 + 6.1026\left(\frac{\text{d.b.h.}}{\text{age}}\right)$	.333
					.768	.591	$Y = 1.5982 + 0.1339\,(\text{d.b.h.}) - 0.0232\,(\text{age})$	.359
Both	138	43	9.6	52.9	.654	.428	$Y = 0.8983 + 4.0380\left(\frac{\text{d.b.h.}}{\text{age}}\right)$	.484

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[a] Adapted from: Taras, Michael A. 1972. (Unpublished data, Work Unit on Grade and Quality of Southern Timber, Southeast. For. Exp. Stn., For. Sci. Lab., Athens, Ga.)

In 1942, Bray and Martin (2) reported on a sample of OSP on which pulping tests were made by the soda, sulfate, and neutral sulfite semi-chemical processes. They concluded that OSP is suitable for the production of strong kraft and bleachable pulps with the sulfate process. The unbleached sulfate pulps were found to be suitable for wrapping papers, the semi-bleached pulps for newsprint, and the fully bleached pulps for high-grade papers. OSP was also readily reduced by the soda and soda-sulfur processes, but the pulps did not possess the softness, opacity, and bulk common to bleached hardwood pulps. The neutral sulfite semi-chemical pulps were somewhat brash, dark-colored, and much weaker than the kraft pulps and were therefore suitable for lower grades of wrapping paper stock and corrugating board. McGovern and Keller (12) found the paper-making qualities of pulps produced by the sulfite process from a sample of OSP to be decidedly inferior to those of sulfite pulps from other southern pines.

Pulping tests conducted on CSP by Martin (14) with the kraft sulfate process showed that pulps from this variety were higher in overall strength and brightness than kraft pulps made from longleaf pine under the same cooking conditions and bleaching requirements. Tests indicated CSP pulps to be suitable for unbleached and bleached kraft papers of high strength.

In 1957, the Hudson Pulp & Paper Corporation conducted a series of tests on OSP with the kraft sulfate process and compared its pulp properties to those of slash pine.[3] OSP was found to pulp satisfactorily under the same conditions as slash pine. The OSP pulp was stronger than slash pine pulp in burst factor (15 percent higher) and tensile strength (14 percent higher). It also produced a denser sheet of about the same softness as slash pine. Tear factor of the OSP pulps, however, was about 19 percent lower than that of slash pine. St. Regis Paper Company in 1956 produced OSP pulps with similar properties.[4] These studies also showed that, in some cases, OSP pulps can be satisfactorily mixed in various proportions with slash pine pulp to produce combination pulps with slightly improved properties over those of slash pine pulps alone.

Pulp Yields

In addition to a species' pulping characteristics, its pulp yields are of prime importance to the pulp and paper industry. How do the pulp yields for sand pine compare with those for other species? This question is answered in part in table 8, which shows the pulp yields for the two varieties of sand pine as well as for longleaf and slash pines. The yields shown in table 8 are computed on the basis of input of ovendry wood chips. On this basis, it can readily be seen that pulp yields for both varieties of sand pine under a variety of cooking conditions are equal to the yields obtained for longleaf and slash pines when cooked under the same conditions.

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[3] Hudson Pulp & Paper Corp. Comparison of strength and softness of regular pine and sand pine kraft pulps. 1957. (Internal office report, Woodlands Division, Palatka, Fla.)

[4] St. Regis Paper Company. Evaluation of sand pine (*Pinus clausa*). 1956. (Internal office report, Pensacola, Fla.)

Pulp yields may also be computed with volume (cord) or green weight as a basis for computation. On this basis, the yield obtained from a given volume of sand pine will be less than that obtained from the same volume of slash or longleaf pine. This difference in yield is attributable to the differences in the relative density or the specific gravity of the wood. On an ovendry basis, a cubic foot of OSP weighs about 26 pounds, whereas slash and longleaf pines average about 33 pounds. If the same cord-weight equivalent used for slash and longleaf pines (about 5, 500 pounds) is also used for OSP, the yield difference would nearly disappear. This method would involve increasing the cord weight or volume by 500 pounds because a cord of OSP weighs about 5, 000 pounds. In view of this difference in cord weight, pulping sand pine alone would require greater digester capacity in order to meet the same production level as that reached in the pulping of slash and longleaf pines.

USES AND MARKETS

Early investigations as well as the more recent ones in the late 1960's show that both varieties of sand pine are suitable for pulping by several processes. The kraft sulfate process, however, appears to be the one best suited to the reduction of sand pine to pulp because of the high yields and superior-quality pulp obtained. The pulp and paper industry, which currently uses the greatest volume of sand pine, will continue to use it in increasing volumes in the future.

The amount of sand pine going into the manufacture of yard and structural lumber for the construction industry is not known. I personally estimate it to be an extremely small amount. Most of the sales of sand pine timber are currently being made to the pulp and paper industry from the National Forests, where the bulk of the volume is located. The construction lumber market is a good potential outlet for some of the volume of sand pine. Tree size and, perhaps, form have been the main deterrents to the use of sand pine for the manufacture of structural lumber. Size, however, need not be a deterrent any longer because of the changes taking place in utilization and logging practices. Sawmills are now using chipper headrigs or are supporting their large mills with small chipper-canters so that they can handle large volumes of small logs 6 to 10 inches d.i.b. A chipper-headrig operation set up for small timber can produce large volumes of lumber suitable for construction purposes. Both varieties definitely have sufficient density for this use.

Table 8.--Pulp yields for both varieties of sand pine and associated yellow pines with the kraft sulfate process

Source	Cooking condition		Pulp yield		
	Active alkali added	Permangànate No.	Screened pulp by weight	Screening	Total crude pulp
	Percent		Percent	Percent	Percent
OCALA SAND PINE					
Wells and Rue (23)	20.0	--	40.1	1.0	41.1
Bray and Martin (2)	13.3	--	47.0	3.4	50.4
	13.3	--	42.8	1.7	44.5
	20.0	--	43.8	.1	43.9
Hudson Pulp & Paper Corp.[a]	18.6	18.5	43.8	.7	44.5
	20.5	23.0	44.8	.5	45.3
Hudson Pulp & Paper Corp.[b]	--	28.5	43.5	3.0	46.6
St. Regis Paper Company[c]	16.8	33.4	45.6	4.5	50.1
	16.8	33.4	45.4	4.1	49.5
CHOCTAWHATCHEE SAND PINE					
Martin (14)	14.0	32.8	47.6	3.3	50.9
	18.0	19.4	45.1	.3	45.4
	20.0	16.6	43.9	.1	44.0
LONGLEAF PINE					
Martin (14)	14.0	31.5	48.4	2.7	51.1
	18.0	19.2	46.0	.2	46.2
	20.0	16.8	44.7	.1	44.8

Table 8.--Pulp yields for both varieties of sand pine and associated yellow pines with the kraft sulfate process (continued)

SLASH PINE

Source	Cooking condition		Pulp yield		
	Active alkali added	Permanganate No.	Screened pulp by weight	Screening	Total crude pulp
	Percent		Percent	Percent	Percent
Hudson Pulp & Paper Corp.[a]	18.6	18.3	43.7	0.7	44.4
	20.5	22.9	47.9	1.0	48.9
Hudson Pulp & Paper Corp.[b]	--	28.2	44.5	3.0	47.0
St. Regis Paper Company[c]	16.8	33.4	48.1	3.8	51.9
	16.8	31.5	47.2	2.4	49.6

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[a] Hudson Pulp & Paper Corp. Comparison of strength and softness of regular pine and sand pine kraft pulps. 1957. (Internal office report, Woodlands Division, Palatka, Fla.)

[b] Hudson Pulp & Paper Corp. Pulp yields from slash and sand pine. 1964. (Internal office report, Woodlands Division, Palatka, Fla.)

[c] St. Regis Paper Company. Evaluation of sand pine (Pinus clausa). 1956. (Internal office report, Pensacola, Fla.)

Although OSP is somewhat low in specific gravity for construction purposes, it can still be used for beams on limited spans. Its low density is not altogether disadvantageous. Low density also means that the wood is lighter and therefore easier to handle, to saw, and to nail without splitting. It would be excluded from areas requiring dense, structural-grade material; however, there are numerous places where it could be used without problems. CSP, whose density is somewhat higher than that of OSP, could be put to structural uses similar to those of loblolly and shortleaf pines because the specific gravity of all three is in the same range.

The rapid expansion of the southern pine plywood industry is placing increasing demands on our forest resources. Although size of raw material is a major factor to this industry, plywood manufacturers are considering using some 4-foot lathes with small spindles in order to cut small-sized material down to a core diameter of less than 3 inches. Veneer made from OSP could be used for the inner plies of a plywood panel. Because of its higher density, CSP could possibly meet the plywood standards and be used for face as well as inner-core plies. When the properties of sand pine and its relatively low density are considered, there is no reason why it cannot be made into veneer without difficulty.

The particle-board industry, which started as a secondary industry that utilized the residue of other industries as its main source of raw material, is now using roundwood as its prime source of such material. Timber size or quality is not important in this industry because the wood is reduced to small particles or flakes and then glued back together. Because of its low density, OSP would be very useful in the manufacture of particle boards of relatively low to medium density.

The "ugly duckling," as this species has been referred to in the literature, has adequate wood properties to meet the requirements for many wood products--the deterrents to its use are factors other than basic wood characteristics.

LITERATURE CITED

1. Bendtsen, B. A. 1968. Mechanical properties and specific gravity of a randomly selected sample of spruce pine. For. Prod. Lab., USDA For. Serv. Res. Pap. FPL-92, 8 pp.

2. Bray, Mark W., and Martin, J. S. 1942. Pulping Florida sand pine (Pinus clausa) for kraft, high-grade papers, and newsprints. South. Pulp & Pap. J. 5(1): 7.

3. Burns, Russell M., and Brendemuehl, R. H. 1969. Yield of a Choctawatchee sand pine plantation at age 28. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-103, 4 pp.

4. Clark, Alexander III, and Saucier, Joseph R. 1969. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part III--Table-Mountain pine (Pinus pungens Lamb.). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-52, 12 pp.

5. _________ and Taras, Michael A. 1969. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part II--Sand pine (Pinus clausa (Chapm.) Vasey). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-51, 14 pp.

6. _________ and Taras, Michael A. 1970. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part VII--South Florida slash pine (Pinus elliottii var. densa Little & Dorman). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-66, 11 pp.

7. _________ and Wahlgren, Harold E. 1970. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part V--Virginia pine (Pinus virginiana Mill.). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-64, 11 pp.

8. DeVall, Wilbur B. 1944. A bark character for identification of certain Florida pines. Fla. Acad. Sci. Proc. 7: 101-103.

9. Howard, Elaine T. 1971. Bark structure of the southern pine. Wood Sci. 3(3): 134-148.

10. _________ and Manwiller, Floyd G. 1969. Anatomical characteristics of southern pine stemwood. Wood Sci. 2(2): 77-86.

11. Koch, Peter. 1972. Utilization of the southern pines. Vol. I. The raw material. Vol. II. Processing. South. For. Exp. Stn., USDA For. Serv. Agric. Handb. 420, 1,663 pp.

12. McGovern, J. N., and Keller, E. L. 1943. Sulfite pulping experiments on sand pine. USDA For. Serv. For. Prod. Lab. Rep. R-1429, 6 pp.

13. Markwardt, L. D., and Wilson, T. R. C. 1935. Strength and related properties of woods grown in the United States. U. S. Dep. Agric. Tech. Bull. 479, 99 pp.

14. Martin, J. S. 1962. Kraft pulping of west Florida sand pine. USDA For. Serv. For. Prod. Lab. Rep. 2248, 6 pp.

15. Saucier, Joseph R., and Clark, Alexander III. 1970. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part IV--Pitch pine (_Pinus_ _rigida_ Mill.). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-63, 16 pp.

16. _________ and Taras, M. A. 1969. Regional variation in specific gravity of seven pines in the southern United States. Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-45, 16 pp.

17. Taras, M. A., and Saucier, J. R. 1968. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part I--Spruce pine (_Pinus_ _glabra_ Walt.). Southeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. SE-34, 15 pp.

18. _________ and Saucier, J. R. 1970. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part VI--Pond pine (_Pinus_ _serotina_ Michx.). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-65, 12 pp.

19. USDA Forest Products Laboratory. 1953. Density, fiber length, and yields of pulp for various species of wood. USDA For. Serv. For. Prod. Lab. Tech. Note 191, 6 pp.

20. _________ 1955. Wood handbook. USDA For. Serv. Agric. Handb. 72, 528 pp.

21. _________ 1956. Physical characteristics and chemical analysis of certain domestic pine woods received at the Forest Products Laboratory for pulping from October 1, 1948, to September 4, 1956. USDA For. Serv. For. Prod. Lab. WFPR-112 (table).

22. _________ 1972. Properties of major southern pines. Part I, Wood density survey, by H. E. Wahlgren and D. R. Schumann. Part II, Structural properties and specific gravity, by B. A. Bendtsen and R. L. Ethington. USDA For. Serv. Res. Pap. FPL 176-177, 68 pp.

Wells, Sidney D., and Rue, John D. 1927. The suitability of American woods for paper pulp. U. S. Dep. Agric. Dep. Bull. 1485, 102 pp.

SAND PINE: CONE AND SEED TRAITS

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Abstract.--Trees of the Choctawhatchee variety of sand pine in western Florida average 1,010 cones per bushel and 56,100 seeds per pound. The Ocala variety in peninsular Florida averages 830 cones per bushel and 47,200 seeds per pound. Cones of the Choctawhatchee variety open readily at 105° F.; cones of the Ocala variety will open if dipped in boiling water and then dried at 105°. The latter, if 2 or more years old, yield seeds of decreased viability, but seeds from both varieties store well at 10-percent moisture content and 25° F. Seeds of the Choctawhatchee variety require stratification for 14 days, but seeds of the Ocala variety, if from new or 1-year-old cones, are nondormant.

The two varieties of sand pine (Pinus clausa (Chapm.) Vasey) differ in their cone characteristics. Variety clausa, often referred to as Ocala sand pine, has persistent, serotinous cones that normally open only after fire. Cones of variety immuginata, or Choctawhatchee sand pine, open on the tree as do those of most other southern pine species.

About 10 years ago, studies were started at Alexandria, Louisiana, to obtain information about collecting and processing cones and treating and storing seeds of both varieties. Many of the findings were published as U. S. Forest Service Research Paper SO-19 (3). The present summary is based on this paper but includes some data acquired later.

For the Alexandria studies, cones from the Choctawhatchee variety were collected on the Eglin Air Force Base Reservation, Walton County, Florida, in mid-September 1962. Collections from the Ocala variety were made in Marion County during early November. For each variety, 15 to 20 trees of uniform size and age were felled to obtain seed. Cones from individual trees were kept separate, and those of the Ocala variety were also segregated by age, i.e., new cones, 1-year-old cones, and cones 2 or more years old. Further segregation by age would have been difficult, because sand pine often forms two or three whorls of cones a year (9). Additional collections in the same year were used to evaluate the effects of cone specific gravity on opening characteristics and seed viability.

CONE SPECIFIC GRAVITY

Cones from 20 trees of the Choctawhatchee variety opened within 48 hours at kiln temperatures of 105° F., despite a range in specific gravity of 0.85 to 1.11. Germination of the seeds from these cones ranged from 80 to 93 percent, except that seeds from one tree averaged 47 percent. Specific gravity and viability were uncorrelated ($r = -0.055$).

The cones from the Ocala variety, which were collected nearly 2 months later than those from the Choctawhatchee variety, ranged from 0.63 to 0.90 in specific gravity. They opened completely after treatments that released the scales. Viability was uniformly high and was unrelated to specific gravity; the lowest germination of any seed lot was 86 percent.

Cones of most southern pines do not open fully if collected at specific gravities above 0.89 (13). In longleaf pine (Pinus palustris Mill.), seeds from cones of the higher specific gravities germinate less well than seeds from mature cones (10).

EXTRACTION

The cones of the Choctawhatchee variety opened within 48 hours in kilns heated to about 105° F.

Cones of the Ocala variety resemble those of other serotinous species in that a resinous substance seals the tips of the scales. Cooper et al. (7) reported that kiln temperatures of 140° to 150° F. opened cones of this variety in 4 hours and that temperatures up to 170° for 2 hours had little effect on seed viability. Temperatures this high are difficult to obtain in commercial practice; most cone kilns in the South are designed to operate at 100° to 105° F. Little and Dorman (9) reported that immersion in boiling water for a few seconds loosened the scales sufficiently to allow seed release after drying.

Several extraction methods were tested on cones of the Ocala variety: (a) kilning, (b) applying a flame directly to the cones, (c) soaking in a solvent, and (d) immersing in boiling water. Kiln temperatures of 130° to 140° F. were required to break the resinous seal, and even then many of the cones opened only partially. Directing a flame on the cones in a wire basket broke the seal in about 5 seconds, but the danger of cone ignition appears to be too great for this technique to have commercial application. A 1:2 mixture of ethanol and benzene, which Roe (11) found to be effective for jack pine (P. banksiana Lamb.); freed the scales in 12 to 18 hours. However, this process is too slow and expensive for practical purposes.

Immersion of Ocala sand pine cones in boiling water was fast and efficient. Scales separated in 5 to 15 seconds, and the cones then opened completely during 24 hours of normal kilning at 100° to 105° F. By placing the cones in water and gradually raising the temperature, it was found that the resinous seal breaks at 125° F., which is near the 122° value that Cameron (5) reported as the melting point of the bonding substance in cones of lodgepole pine (P. contorta Dougl.) and jack pine.

Except for the controls, in which some seeds were damaged when the scales were pried apart with a knife, none of the opening treatments affected germination significantly:

Treatment	Germination (Percent)
Control (scales pried apart)	78
Boiled for 15 seconds	85
Alcohol-benzene soak	86
Direct flame	92
Kilned at 140° F.	91

Because immersion in boiling water appeared to be the most satisfactory means of opening cones of the Ocala variety, a test was run to determine how long cones could be immersed without injury to the seeds. The controls were opened by direct flame instead of by prying the scales apart. Immersion for 0.5 minute reduced germination by 6 percentage points, and viability declined significantly with each increase beyond 0.5 minute:

Immersion (Minutes)	Germination (Percent)
0.0	90
.5	84
1.0	77
2.0	15
5.0	0

Thus, cones of this variety should be kept in the water only until the scales separate--usually within 15 seconds.

In recent years, Ocala sand pine cones have been processed commercially by submerging 1-bushel lots, held in burlap bags, in vats of boiling water. Although the scales will separate when the temperature of the water is as low as 125° F., boiling water separates them much faster and also provides a wide margin to offset cooling when the bags are immersed.

PROCESSING

Commercial techniques for processing cones and seeds of sand pine are identical to those for other southern pine species. Consideration should be given to factors known to reduce storability, such as damage to seedcoats in dewinging and long-term kilning at high temperatures (4).

Liquids of varying specific gravities were tried for separating full and empty seeds for research purposes. Absolute or 95-percent ethanol gave almost perfect results, with full seeds sinking and empty seeds floating. Soaks for as long as 5 minutes in ethanol did not lessen viability; in fact, seed thus treated germinated faster and more completely than the controls.

Recent results have shown, however, that when seeds of slash pine (P. elliottii Engelm.) and spruce pine (P. glabra Walt.) are soaked in ethanol, they lose viability during storage (2). The alcohol apparently becomes toxic to the seed after lengthy contact. Drying for extended periods after soaking alleviates some of this effect, but flotation should be delayed until just before the seeds are used.

SEED YIELDS

In all determinations, the Choctawhatchee variety averaged 1,010 cones per bushel and ranged from 630 to 1,310. Cones of the Ocala variety, which are larger, averaged 830 per bushel and ranged from 450 to 1,100. Although the trees selected for collection were relatively fruitful, most yielded less than 1 bushel of cones, and many yielded less than 0.5 bushel.

Seed yields were determined for five cones from each of 18 Choctawhatchee sand pines. The average yield was 42 seeds per cone--28 sound and 14 empty. No comparable measurements were made for the Ocala variety, but the average yield from 25 new cones from each of three trees was 37 sound seeds per cone.

After the seeds were cleaned of wings and trash and dried to about 10-percent moisture content, yields for both varieties averaged 0.62 pound per bushel of cones. Yields per bushel of cones from individual Ocala sand pines ranged from 0.3 to slightly over 1 pound. The 1961 (1-year-old) cones consistently yielded more seed than did the new, 1962 cones--0.77 as compared to 0.58 pound. Such year-to-year variations are common in pines (13).

Seeds of the Ocala variety averaged 47,200 per pound, with a range from 26,000 to 67,800. Seeds of the Choctawhatchee variety were generally smaller, averaging 56,100 per pound and varying between 40,800 and 58,900. These determinations were made with seeds that were 100 percent sound. The Woody-Plant Seed Manual (12) reports 75,000 seeds per pound, with a range from 65,000 to 85,000, but it does not distinguish between varieties. The values reported were probably derived from samples with high proportions of empty seed.

VIABILITY BY CONE AGE

Cooper and Schopmeyer (6) found a strong relationship between age of Ocala sand pine cones and seed viability. They reported germination of 76 percent for seeds from new cones and 27 percent for seeds from 5-year-old cones.

To evaluate this relationship further, Barnett and McLemore (3) tested the viability of seeds from cones of three age classes from 15 Ocala sand pines. A breakdown into more than three age groups was impractical because of multiple whorls and similar coloration of old cones.

Viability decreased with each increase in age of cones (table 1). The difference of 7 percentage points--93 versus 86 percent--between new and 1-year-old cones was relatively small compared to the drop of 37 percentage points for seeds 2 or more years old.

Table 1.--Germination of seeds of Ocala sand pine, by cone age and individual tree[a]

Tree number	Seed extracted from-- New cones	1-year-old cones	2-year-old and older cones
	- - - - - - - - - - Percent	- - - - - - - - - -	
1	90	87	70
2	94	84	65
3	93	87	67
4	94	88	72
5	95	84	68
6	86	72	22
7	92	94	60
8	92	76	34
9	93	95	8
10	89	88	84
11	100	95	48
12	90	95	82
13	85	69	14
14	98	92	66
15	98	90	74
Average	93	86	56

[a] Adapted from tabular data in Barnett and McLemore (3).

Germination of both new and 1-year-old seeds was fairly uniform among individual trees. Older seeds varied widely, ranging from 8 to 84 percent. This variation probably was due to differences in individual trees and in cone age. To assure high-quality seeds from the Ocala variety, collections should be limited to new and 1-year-old cones. New cones are readily distinguished by their light brown color, whereas 1-year-old cones are dark brown. Older cones are a weathered gray, are often covered with lichens, and occur in the interior portion of the crown.

The effects of cone storage on viability were evaluated by storing three individual-tree lots of Ocala sand pine cones at a constant temperature of 72° F. Seeds were obtained by immersing the cones in boiling water and then drying at 100° F. Viability tests were conducted initially and after 3, 6, and 9 years.

Germination of seeds from Ocala sand pine after 9 years of cone storage averaged 26 percent, as compared to 93 percent initially and 90 and 54 percent after 3 and 6 years (table 2). Viability varied markedly among trees. These tests show that serotinous cones provide a suitable environment for maintenance of viability for several years.

Table 2. --Germination of Ocala sand pine seeds initially and after cone storage for 3, 6, and 9 years at 72° F.

Tree number	Germination when tested after--			
	0 years	3 years	6 years	9 years
	Percent			
3	93	87	48	16
4	94	92	42	12
7	92	91	73	49
Average	93	90	54	26

PREGERMINATION TREATMENTS

Seed dormancy and methods of speeding germination were studied with lots from 10 trees of both varieties. Seeds of the Ocala variety were further subdivided into those from cones of three ages for each tree. Four treatments plus a control were evaluated for the Choctawhatchee variety and two plus a control for the Ocala variety (table 3).

Seeds of the Choctawhatchee variety were mildly dormant. Stratification on a peat-sand medium for 14 days boosted both rate and total amount of germination, but increasing the length to 28 days gave little added response. Soaking in water at 34° F. was better than soaking in 1-percent hydrogen peroxide.

Table 3.--Germination of Choctawhatchee and Ocala varieties of sand pine seed subjected to various pregermination treatments[a]

CHOCTAWHATCHEE VARIETY

Pregermination treatment	Peak germination	Germination value[b]	Final germination[c]
	Day		Percent
None	17	15.4	88
14-day stratification	11	26.3	93
28-day stratification	10	27.9	94
24-hour soak in water	13	20.7	92
24-hour soak in H_2O_2	14	18.1	89

OCALA VARIETY

Pregermination treatment	Peak germination	Germination value[b]	Final germination[c]
New cones			
None	10	32.0	94
14-day stratification	9	34.3	96
28-day stratification	8	35.9	93
1-year-old cones			
None	10	24.1	89
14-day stratification	10	26.6	90
28-day stratification	10	25.3	84
2-year-old and older cones			
None	15	10.9	70
14-day stratification	14	8.2	54
28-day stratification	11	5.7	43

[a] Adapted from tabular data in Barnett and McLemore (3).

[b] Czabator's (8) germination values, which take into account both speed and completeness of germination, are presented so that treatments can be compared.

[c] Germination tests conducted with 100-percent sound seed from 10 trees of each variety.

Dormancy of Ocala sand pine seeds varied with cone age. Seeds from new and 1-year-old cones germinated promptly without presowing treatment, and none of the treatments stimulated germination significantly. Older seeds were slightly dormant. Stratification speeded germination but decreased total viability substantially; thus it is not recommended for Ocala sand pine seeds.

A comparison of treatments common to both varieties indicates that fresh Ocala sand pine seeds performed slightly better than Choctawhatchee sand pine seeds stratified for 28 days.

STORAGE

Sand pine seeds are easily stored (1). When held in sealed containers at all possible combinations of 6-, 9-, 12-, and 15-percent moisture contents and 0°, 25°, and 34° F. temperatures, Ocala sand pine seeds from new and 1-year-old cones remained almost uniform in viability over a 5-year period. Even after 5 years, germination of seeds from new cones exceeded 95 percent and that of 1-year-old cones exceeded 84 percent. With other southern pines, germination declines fastest when seeds are stored at high temperatures and moisture contents.

Seeds of the Choctawhatchee variety apparently are more sensitive to storage conditions than are those of the Ocala variety. Although there were no losses in viability after 1 or 3 years (table 4), germination after 5 years averaged 75 percent for storage at 0° F., 70 percent for storage at 25°, and 61 percent for storage at 34° F. Even seeds held under the most ideal conditions for 5 years germinated less than the initial 86 percent, but storage at 0° and 25° F. was significantly better than at 34° F. Moisture contents, ranging from 6 to 15 percent, had no effect on storability. Apparently, temperature is more important than moisture content in preserving viability of these seeds.

The sand pine seeds in this study kept well under a wide range of conditions, but moisture contents of 10 percent or less and subfreezing temperatures are recommended for long-term storage. These conditions will allow a margin of safety for seed lots weaker than those tested.

Table 4.--Viability of Choctawhatchee sand pine seeds after 1, 3, and 5 years of storage[a]

Storage conditions[b]		Viability after storage for--		
Temperature (° F.)	Moisture content (percent)	1 year	3 years	5 years
		- - - -	Percent	- - - -
0	6	86	92	72
	9	92	94	78
	12	87	95	69
	15	86	94	81
25	6	86	94	76
	9	84	94	72
	12	83	93	64
	15	86	90	68
34	6	85	91	60
	9	87	93	58
	12	84	90	67
	15	85	89	59
Average		86	92	69

[a] Adapted from tabular data in Barnett (1).

[b] Initial viability was 86 percent.

CONCLUSIONS

The findings of these studies have practical applications:

1. Choctawhatchee sand pine cones collected after September 15 open readily at a kiln temperature of 105° F. even though their specific gravities may range from 0.85 to 1.11. No relationship has been established between specific gravity and viability. The serotinous cones of the Ocala variety may be collected at any time after they have turned brown, as maturity is then assured.

2. Immersion in boiling water for 15 seconds followed by 24 hours of kilning at 100 to 110° F. efficiently opens cones of the Ocala variety.

3. Both cones and seeds are larger in the Ocala variety. Cones of the Choctawhatchee variety average 1,010 per bushel whereas those of the Ocala variety average 830. The Choctawhatchee variety averages 56,100 seeds per pound, and the Ocala variety averages 47,200.

4. Flotation in 95-percent ethanol is an effective means of sorting empty seeds from full ones. Soaking for as long as 5 minutes does not harm viability, but flotation should be done just before the seeds are used.

5. Commercial collections of Ocala sand pine cones should exclude those 2 or more years old, because seeds from such cones will be less viable than those from newer cones.

6. Seeds of the Choctawhatchee variety are mildly dormant, and stratification for 14 days increases both speed and completeness of germination. Cold stratification is superior to soaking in water or hydrogen peroxide.

7. Stratification is not recommended for seeds of the Ocala variety. Seeds from new and 1-year-old cones are nondormant. Seeds from cones 2 or more years old are apt to be dormant, but their germination will be low at best and stratification will reduce it further.

8. Seeds of the Ocala variety store well under a variety of conditions for periods up to 5 years. Seeds of the Choctawhatchee variety are more sensitive to storage conditions, and temperature apparently is more important than moisture content in preserving viability. All seeds should be dried to 10-percent moisture content and placed at subfreezing temperatures for long-term storage. These conditions will allow a margin of safety for weaker seed lots.

LITERATURE CITED

1. Barnett, J. P. 1970. Storage of sand pine seeds. USDA For. Serv. Tree Plant. Notes 21(4): 11-12.

2. _________ 1971. Flotation in ethanol reduces storability of southern pine seeds. For. Sci. 17: 50-51.

3. _________ and McLemore, B. F. 1965. Cone and seed characteristics of sand pine. South. For. Exp. Stn., U. S. For. Serv. Res. Pap. SO-19, 13 pp.

4. _________ and McLemore, B. F. 1970. Storing southern pine seeds. J. For. 68: 24-27.

5. Cameron, H. 1953. Melting point of the bonding material in lodgepole pine and jack pine cones. Can. Dep. Resour. & Dev. Silvic. Leafl. 86, 3 pp.

6. Cooper, R. W., and Schopmeyer, C. S. 1953. Viability of sand pine seed. USDA For. Serv. Southeast. For. Exp. Stn. Res. Notes 23, 2 pp.

7. _________ Schopmeyer, C. S., and McGregor, W. H. D. 1959. Sand pine regeneration on the Ocala National Forest. U. S. Dep. Agric. Prod. Res. Rep. 30, 37 pp.

8. Czabator, F. J. 1962. Germination value: an index combining speed and completeness of pine seed germination. For. Sci. 8: 386-396.

9. Little, E. L., Jr., and Dorman, K. W. 1952. Geographic differences in cone-opening in sand pine. J. For. 50: 204-205.

10. McLemore, B. F. 1959. Cone maturity affects germination of longleaf pine seed. J. For. 57: 648-650.

11. Roe, E. I. 1963. Seed stored in cones of some jack pine stands, northern Minnesota. Lake States For. Exp. Stn., U. S. For. Serv. Res. Pap. LS-1, 14 pp.

12. USDA Forest Service. 1948. Woody-plant seed manual. U. S. Dep. Agric. Misc. Publ. 654, 416 pp.

13. Wakeley, P. C. 1954. Planting the southern pines. USDA For. Serv. Agric. Monogr. 18, 233 pp.

NURSERY PRACTICES USED FOR SAND PINE

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Abstract.--Nursery practices used for sand pine by the Florida Division of Forestry are summarized. These include site selection, soil management and fumigation, seed treatment and sowing, seedbed mulching and weeding, insect and disease control, and the growth, lifting, grading, packaging, and shipping of seedlings.

The species of seedlings produced in forest tree nurseries in the South have for the most part been determined by commercial wood value. Interest in nursery production of sand pine started through the efforts of Armstrong Cork Corporation, which provided 1 pound of seeds to the Florida Division of Forestry's Munson Nursery in west Florida in 1956. These seeds were planted, and nursery practices commonly used for slash pine were applied. In December of 1956, 8,000 sand pine seedlings were ready for outplanting.

Since 1956, over 60 million sand pine have been produced in the Florida Division of Forestry nurseries. The results of the 1956 nursery planting revealed that not all of the nursery practices used for slash pine are successful with sand pine, but in general many of the same practices applied.

This paper will summarize each phase of the nursery operations and practices that are currently being applied to sand pine.

SITE SELECTION

The selection of the site within the nursery may mean the difference between success or failure. This is especially true when soil types in the nursery vary. Our experience has taught us to avoid poorly drained soils and, most especially, heavily textured clays. Well-drained sandy loams are best suited for growing sand pine. Heavily textured, poorly drained soils appear to encourage root pathogens; most often, seedling growth and development are poor. When heavily textured nursery soils are sown to sand pine, irrigation should be watched closely and limited to that necessary to produce a crop. Should the season be unusually wet, the seedling crop growing on heavily textured clay soils could be a complete failure.

SOIL MANAGEMENT

Soil management procedures for growing sand pine in the nursery are basically the same as those used for the major southern pines. A soil pH of 5.5 to 6.0 is acceptable. Because this species does best on well-drained, sandy loams, soil organic matter may be less than the 3 percent most nurserymen like to maintain.

Nursery soils are sampled and tested annually. All Division of Forestry nursery soils are tested by the University of Florida Soils Testing Laboratory. The fertilizer recommendations are made by Dr. W. R. Pritchett and Extension Forester Tom Herndon. It should be pointed out for the benefit of those from other states that the ammonium acetate method of determining available phosphorus is used by the University of Florida Soils Laboratory. This method may differ from the method used in other testing facilities. We like to maintain our potassium level at 250 pounds per acre and our phosphorus level at 100.

When phosphorus is needed, it is applied in the form of superphosphate before planting in early April. All mixed fertilizers are also applied at this time. Nitrogen and potassium are most often applied as a top dressing after the seedlings are 3 weeks old. In cases where nitrogen and potassium are extremely low, we may make pre-plant applications. The first top dressing with nitrogen is most often made in mid-June and should not exceed 50 pounds per acre. Additional applications of ammonium nitrate are made in July and early August, when additional height growth is desired.

Potassium is applied in the form of muriate of potash or sulfate of potash. We favor the sulfate of potash in areas where the pH value may be 6.0 or above. The potash is applied as a top dressing in July. The total amount needed will determine whether we make split applications or only one application. Chlorosis, a nutrient deficiency, is not uncommon in nursery beds of sand pine. It is more often found in the areas of heavy soil but may show up when nitrogen is deficient. We normally apply 50 pounds of ammonium nitrate. If this application does not correct the condition, we apply iron chelate or iron sulfate.

SOIL FUMIGATION

The Florida Division of Forestry nurseries apply 68-percent methyl bromide at a rate of 600 pounds per acre 2 weeks before the seeds are sown. Fumigated soils are cropped 2 years in succession before rotation with a cover crop for 2 years.

SEED TREATMENT

Seeds are removed from cold storage and treated with Arasan® S-42 and aluminum flakes before sowing. Stratification has not been revealed to produce any increase in germination; therefore, the seeds are not stratified. Seed treatment is accomplished through the use of a small cement mixer. After treatment, the seeds are dried on a concrete floor by constant rotation with a rake.

SEED SOWING

The established rates of sowing seeds are designed to produce 27 to 30 plantable seedlings per square foot of seedbed. Current seed tests are used in computing the sowing rates. The seed lots sown by the nurseries usually average 78- to 82-percent germination and a purity of 97 to 99 percent. Past experience has dictated that we figure our nursery survival at 60 percent in order to produce the desired number of plantable seedlings per square foot. It is evident that 60-percent nursery survival is low, and we are seeking methods to attain better survival.

Seed is sown with the conventional Whitfield® seeder. This seeder is not designed for seeds as small as those of sand pine, and we experience difficulty in regulating it to our desired densities of seed sowing. For this reason, we are considering the purchase of a Stan Hay® seeder for use in sowing both slash and sand pine seedbeds. The latter seeder is designed for vegetable crops and has the flexibility required for precise placement of most conifer seeds on nursery beds. Nursery sowing of sand pine seed is done in late April and coincides with the spring sowing of other conifer species in the Southeast.

SEEDBED MULCHING

After seeding, the seedbeds are mulched with chopped pine straw. The pine straw is not treated for control of weed seeds because the use of herbicides directly over the seedbeds after mulching appears to be more economical. The chopped straw does not require removal after the seedlings have germinated. It is applied with a modified manure spreader, and we try to mulch the beds to a depth of 1/4 to 1/2 inch. A number of nurseries in the Southeast have used the Hydro Seeder® and wood fiber mulch for seedbed mulching. Our results with this seeder on sand pine have not been acceptable. Because considerable time is required for nursery personnel to rake, haul, and chop, we shall continue to make trial applications with the Hydro Seeder® on sand pine in an effort to reduce the amount of pine straw needed for mulching.

IRRIGATION

Irrigation is applied immediately after sowing, and all seedbeds receive approximately 1/4 inch of water daily until germination is complete (which usually requires from 7 to 10 days). The decision on whether to irrigate after germination is usually left to the nurseryman and depends upon rainfall and the nurseryman's ability to determine soil moisture requirements. Tensiometers have proved successful in determining when irrigation is needed and are now being purchased for the future production of crops. After the seedlings attain a height of 7 inches, irrigation rates are decreased and limited to the amounts necessary to ensure healthy seedlings. We strive to reach this point by September in order to begin the conditioning period before lifting in December. In order to condition the seedlings to withstand the shock of lifting, shipment, and transplanting, they receive no fertilization and a minimum of irrigation from September to December.

INSECT AND DISEASE CONTROL

Insect damage to sand pine seedlings has been almost nonexistent. The red spider is the only insect for which control measures have been used: when this insect is present, usually one spray with malathion is applied in late August.

Our program of soil fumigation gives adequate disease control, and I am not aware of any problems in the nursery with black root rot.

Sand pine appears to be resistant to fusiform rust and may not need ferbam sprays for control of this rust. In the past, we have applied ferbam at the rate of 4 pounds per acre as a preventative measure because we were not sure about sand pine's resistance to fusiform rust.

SEEDBED WEEDING

All efforts are made in the fumigation program to control the seeds of noxious weeds and grasses and thereby reduce the amount of hand weeding necessary to promote seedling growth. Through the trial and error process, it was found that sand pine could withstand sprays of mineral spirits of the same volume and number of applications as those withstood by slash pine. Sprays of mineral spirits amounting to 15 gallons per acre 2 weeks after germination and progressing up to 35 gallons per acre in July are not uncommon with this species; such sprays never exceed two applications per week. I must emphasize that close field observations should accompany the spray program with mineral spirits in order to detect any foliage burn that might result from the mineral spirits. A spray repeated too closely after such a burn can cause severe injury to small seedlings. Pressure of the spray rig should never exceed 50 pounds, and a pressure of 30 pounds is most desirable.

GROWTH OF NURSERY SEEDLINGS

In general, the growth of sand pine in the nursery can be compared with that of loblolly pine. Sand pine's first flush of growth occurs after that of slash pine by a 2-week margin, generally in late June. The second flush should begin in late July or early August, terminating in late September or mid-October with a winter bud set. The desirable top growth from the root collar appears to be 8 inches. Root development is normally commensurate with height growth. Small seedlings often have a very fibrous root system and appear to survive well after outplanting.

LIFTING, GRADING, PACKAGING, AND SHIPPING OF SEEDLINGS

The lifting of seedlings from the nursery beds begins in early December. To date, we have not been able to lift sand pine with the mechanical lifter. The high resin content of the needles causes a buildup of resin on the lifter belts, and the seedlings do not release from the belts as well as do those of slash pine. This problem may be partly due to late growth of the seedlings and to succulent foliage. For the past 2 years, seedlings in the nursery have not been as large as those of slash pine. Average top heights have been about 5 inches; this diminished size has also contributed to the failure in mechanical lifting of these seedlings. Consequently, the lifting of sand pine is done by hand. The lifting blade is used to undercut the beds before lifting is begun. This blade utilizes an agitating mechanism which loosens the soil and allows the seedlings to be lifted with most of the root system intact.

The seedlings are placed in metal tubs in the field as they are lifted and are then transported to the packing shed on a field trailer. Lifting is mainly governed by the existing orders to be filled; when possible, the lifting and packing are done on the same day that the seedlings are to be shipped. We do not like to hold sand pine in storage for more than 24 hours under any conditions.

Grading of seedlings on the conventional grading table in the nursery has been discontinued as of the 1971-72 crop. This procedure is used only in extreme circumstances when field grading is less economical. By more precise rates of sowing, lower densities in the seedbed, and careful sizing of the seeds, we have attempted to deliver to the landowner a seedling which equals those from our conventional grading belt. When grading is necessary, we grade in the field before lifting begins. Crews weed the beds of cull seedlings before December.

Seedlings are sold on an estimated per-thousand basis. The estimated count is made by weighing the seedlings. All seedling weights are derived by a continuing counted sample. Weights are recorded and averaged at the end of each day. This process has proved to be sufficiently accurate for purposes of distribution. Most seedling bales will be within plus or minus 10 percent.

Seedlings are packaged in the conventional Forest Service bales. Kim Pac® fiber is used as the moisture-holding medium in the bales. Normal bales contain 2,000 seedlings. The bales contain a $1\frac{1}{4}$- by $1\frac{1}{4}$- by 28-inch wooden stake which gives rigidity for handling purposes. All bales are strapped about 5 inches from each end with a band of steel.

Most sand pine seedlings are picked up at the nursery by the landowner or contractor who will be planting the seedlings. Small orders are often delivered by the nursery's truck to the various headquarters of the Division of Forestry throughout the state. All persons who request delivery by nursery truck are notified as to the approximate time the seedlings will arrive at District headquarters.

Purchasers of sand pine seedlings are requested to plant the seedlings as soon after receiving them as possible. Past experience of storing sand pine in the seedling bale indicates that extended storage will decrease planting survival beyond that of seedlings planted within 48 hours of lifting from the nursery beds.

TEMPERATURE EFFECTS ON GROWTH, ASSIMILATION, AND BUD DEVELOPMENT OF SAND PINE [1]

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Abstract.--The Choctawhatchee and Ocala varieties of sand pine differ in their reaction to temperature. Both dry matter accumulation during the first vegetative season and bud development during the second varied according to variety. Choctawhatchee sand pine, the more northern variety, was more tolerant of low temperature but showed slightly lower dry matter accumulation at higher temperatures than did the Ocala variety. Also, more warmth is required for breaking dormancy in the northern variety. The net assimilation rate of sand pine and its dependence on temperature regimes are comparable to those of other species of conifers.

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INTRODUCTION

The two sand pine (Pinus clausa (Chapm.) Vasey) varieties exist almost exclusively in deep sands of coastal and peninsular Florida: Choctawhatchee sand pine (Pinus clausa var. immuginata Ward) in northwest Florida and Ocala sand pine (Pinus clausa var. clausa Ward) in the peninsular area. A number of isolated stands appear in areas other than the two major centers, but there are extensive zones where the species does not occur because of a lack of suitable habitat. Inundation of most of Florida following the last ice age, leaving several isolated islands, is probably a main contributing factor to observed variation.

The two major regions of the sand pine range differ slightly in climate, especially in winter temperature. The purpose of this study was to determine the effect of temperature on seedling growth characteristics of the species. The response of young seedlings to greenhouse conditions and to various temperature regimes in controlled environment chambers was studied.

MATERIALS AND METHODS

Seed used in this study were from broad-base collections made on the Ocala National Forest (Ocala variety) and the Eglin Air Force Base Reservation (Choctawhatchee variety) during the fall of 1968. Seed were sown in flats during mid-December and placed in the greehouse; germination took place in about 2-1/2 weeks. Newly germinated seedlings, their cotyledons still encased in the seedcoat, were transplanted to a sand media in peat pots, placed in flats, and immediately transferred to three temperature regimes in controlled environment chambers. These plants were sampled for dry matter determinations and growth analyses after 8 weeks and 11 weeks. Except for the Ocala variety in the hot chamber, harvests consisted of from 100 to 120 seedlings from each variety at each temperature condition. Because of early mortality (damping off), harvests of the Ocala variety in the hot chamber consisted of only 20 seedlings. All samples were dried at 105° C. to a constant weight.

One-year-old nursery grown seedlings were used for the study of dormancy and bud development. One group was lifted bare root, transplanted into pots, and placed in a heated greenhouse under favorable conditions during December. These seedlings were observed over a period of 2 months. During February, another two groups from two different nurseries were lifted, soil intact, planted directly in pots with a transplant tool, and placed in the three temperature regimes in the growth chamber.

Soils in the two major regions of the sand pine range are similar. Also, there is little difference in precipitation, the Ocala region being slightly drier during winter. However, meteorological records indicate some differences occur in winter minimum, maximum, and mean temperatures. Therefore, it was decided to adjust the temperatures of the three growth chambers to represent average winter, spring, and summer conditions in the north-central Florida region.

Average summer temperature of both regions is about 27° C., but average winter temperatures of the two regions differ by about 3° C.: the average winter temperature is 12° C. in the Choctawhatchee region and 15° C. in the Ocala region. There is a fairly constant, about 12° C., monthly amplitude between mean maximum and minimum temperature for both regions throughout the year. Kramer (7) showed that large differences between day and night temperatures stimulated growth of loblolly pine seedlings. Therefore, the three growth chambers were adjusted to approximately cover the entire range of average temperature variations in the sand pine range:

Hot chamber	32° C. day - 21° C. night
Medium chamber	24° C. day - 13° C. night
Cool chamber	15° C. day - 4° C. night

Relative humidity ranged from 60 to 90 percent. A 12-hour photoperiod was maintained with a mixture of incandescent and fluorescent lamps at 2,000 ft.-c. At every cycle, dawn and dusk were imitated by 15 minutes of incandescent light alone.

RESULTS

In the experiment with seedlings germinated from seed, almost the same pattern of ecotypic differentiation was observed at both sampling dates (fig. 1). The Choctawhatchee variety had higher dry matter accumulation in the cold chamber, but the Ocala variety had higher accumulation in medium and hot chambers. At the first sampling, there was a highly significant interaction between seed sources and temperatures. The same trends were present at the second sampling, but they were not statistically significant.

Student's t tests between races within chambers showed, for both sampling dates, significant differences at low temperature but not at medium temperature. The Ocala data were insufficient to make comparisons at high temperature. Significant differences in total dry matter accumulation resulted mainly from stem and needle differences whereas root dry matter was usually within the error limits.

Within the investigated range of temperatures, dry matter accumulation by sand pine seedlings was almost directly proportional to the average temperature of the growth conditions. However, this pattern is only valid for the aboveground portion of the seedling; growth of root systems was distinctly reduced in the hot chamber.

Net assimilation rates (expressed as mg. of dry matter increase per g. of dry needle matter per day) for the five fully representative groups of data are presented in table 1. Net assimilation rates of both varieties decreased with increasing temperature, but varietal trends were not quite the same.

Table 1.--Net assimilation rate in mg. of dry matter per g. of dry needle matter per day calculated according to the formula

$$NAR = \frac{(W_2 - W_1) \times 2}{(A_1 + A_2)(t_2 - t_1)}$$

Seed source	Temperature conditions °C. (day/night) Cool 15/4	Medium 24/13	Hot 32/21
Ocala	61.9	30.1	--
Choctawhatchee	59.2	35.1	32.6

W_1, W_2 - total dry matter at the first and second harvest

A_1, A_2 - dry weight of needles

$(t_2 - t_1)$ - time interval in days between the two samplings.

Bud development of one-year-old seedlings was determined at several day intervals (fig. 2). Appearance of new needles from bud scales was the criterion assumed for bud breaking. Data were expressed as percentage of the total number of plants examined that broke dormancy at each time interval. The Ocala variety broke dormancy before the Choctawhatchee variety under all temperature conditions in the greenhouse and in the three temperature regimes in the growth chamber. Seedlings placed in the greenhouse during December broke dormancy more slowly than those placed in growth chambers during February. In the greenhouse, the varietal difference exceeded 2 weeks, but in all temperature regimes in the growth chamber the differences averaged 7 to 10 days. There was no difference in the reaction of plants from two different nurseries.

DISCUSSION

Considerable information indicates that temperature is an important factor in ecotypic differentiation of plants (2, 5, 11).

The sand pine experiments reported here clearly showed a variety-temperature interaction. Although analysis of meteorological data did not indicate a great diversity between the conditions of northwestern and central Florida, slight differences in climate apparently influenced varietal differentiation of sand pine. Dry matter accumulation and net assimilation rates of the two races were different, as was the period of spring development of apical buds. Again, it must be stressed that both main regions of sand pine differ mainly in winter temperatures; in the north, mean winter temperature is lower and the number of frost days is considerably higher. Citrus, for example, grows well in the Ocala region but does not occur in the Choctawhatchee region or even 25 miles north of the Ocala National Forest.

Differences in bud development in the greenhouse and in the growth chamber (fig. 2) indicate both varieties may differ not only in requirement of temperature increase during the spring period, but also possibly in their characteristics of dormancy. Perhaps Ocala sand pine has no typical winter dormancy because such a short period of favorable conditions promotes flushing considerably in advance of Choctawhatchee sand pine. Difference in time of bud development could account for the different flowering dates which make gene exchange between the two varieties even more difficult. Also, difficulty in establishing Ocala sand pine plantations is probably due to the absence of a winter-type dormancy in this variety. Harms (4) observed relatively better survival of Choctawhatchee compared with Ocala sand pine plantings in Georgia and South Carolina. He attributed the poorer survival of Ocala sand pine to freezing soon after plantation establishment. Several attempts to establish seed orchards of Ocala sand pine seedlings in the north-central Florida area by the University of Florida Tree Improvement Cooperative failed for apparently similar reasons. That is one factor that prompted this study, for it was generally known that better survival was obtained with the Choctawhatchee variety. Goddard and Strickland (3) report similar observations in a sand pine provenance trial.

In general, data presented in this work contribute to our knowledge of plant-temperature relationships. In our experiments, as in those of Brix (1) with Douglas-fir seedlings, a decrease in net assimilation rate occurred at higher temperatures. The decrease could be attributed to increased respiration. Pharis and Woods (8) found the maximum rate of photosynthesis of Choctawhatchee sand pine occurred at 23° C., but respiration increased even above 48° C. However, it is also possible that decreased net assimilation with increased temperature is also due to differences in the seedlings' developmental stages in the different temperature regimes. It is well known that photosynthesis per unit of foliage weight decreases as development stage advances.

Comparison of these sand pine data with some other authors' data on northern conifers (Brix (1) and Sorensen (10), with *Pseudotsuga menziesii*; and Kramer (7), with *Pinus taeda*) indicates sand pine is more tolerant to higher temperatures than more northern species.

The net assimilation rates reported here, 30 to 60 mg. per g. of dry needle matter per day, are comparable with those reported by Rutter (9) and Jarvis and Jarvis (6) for Scots pine (*Pinus silvestris* L.) seedlings.

LITERATURE CITED

1. Brix, H. 1967. An analysis of dry matter production of Douglas-fir seedlings in relation to temperature and light intensity. Can. J. Bot. 45: 2063-2072.

2. Duncan, W. G., and Hesketh, J. D. 1968. Net photosynthetic rates, relative growth rates, and leaf numbers of 22 races of maize grown at eight temperatures. Crop Sci. 8: 670-674.

3. Goddard, R. E., and Strickland, R. K. 1973. Genetics of sand pine and the program for superior tree selection. *In* Sand pine symposium proceedings 1972. USDA For. Serv. Southeast. For. Exp. Stn.

4. Harms, W. R. 1969. Sand pine in the Georgia-Carolina sandhills: third-year performance. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-123, 3 pp.

5. Hiersey, W. M., and Milner, H. W. 1965. Physiology of ecological races and species. Annu. Rev. Plant Physiol. 16: 203-216.

6. Jarvis, P. G., and Jarvis, M. S. 1964. Growth rates of woody plants. Physiol. Plant. 17: 654-666.

7. Kramer, P. J. 1957. Some effects of various combinations of day and night temperatures and photoperiod on the height growth of loblolly pine seedlings. For. Sci. 3: 45-55.

8. Pharis, R. P., and Woods, F. W. 1960. Effects of temperature upon photosynthesis and respiration of Choctawhatchee sand pine. Ecology 41: 797-799.

9. Rutter, A. J. 1957. Studies in the growth of young plants of Pinus silvestris L. I. The annual cycle of assimilation and growth. Ann. Bot. N.S. 21: 399-426.

10. Sorensen, F. C. 1964. Photosynthesis, respiration, and dry matter accumulation of Douglas-fir seedlings from different geographic sources and grown at different temperatures. Ph.D. Diss., Oreg. State Univ., Corvallis.

11. Sweet, G. B., and Wareing, P. F. 1968. A comparison of the rates of growth and photosynthesis in first year seedlings of four provenances of Pinus contorta Dougl. Ann. Bot. N.S. 32: 721-734.

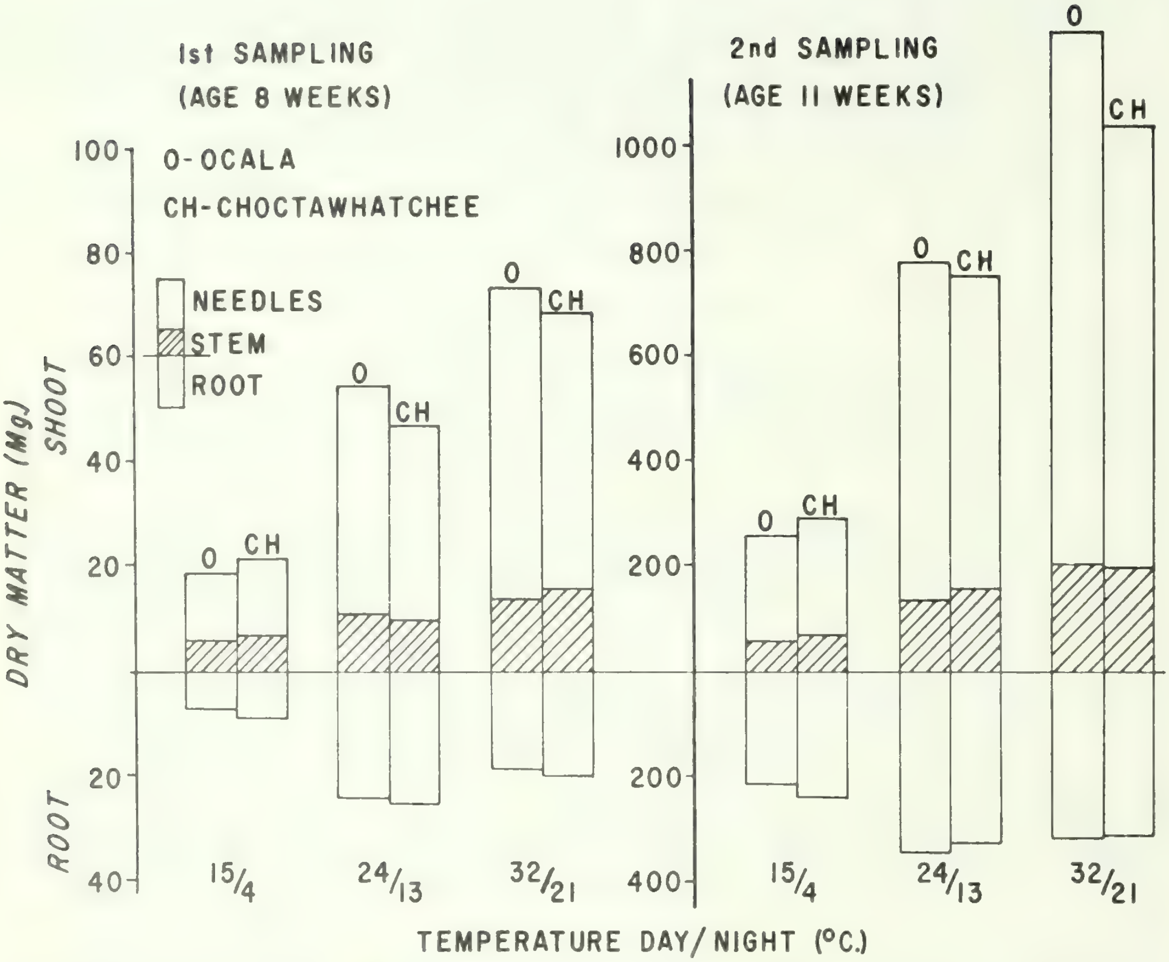

Figure 1.--Comparison of dry matter accumulation between varieties under different temperature regimes.

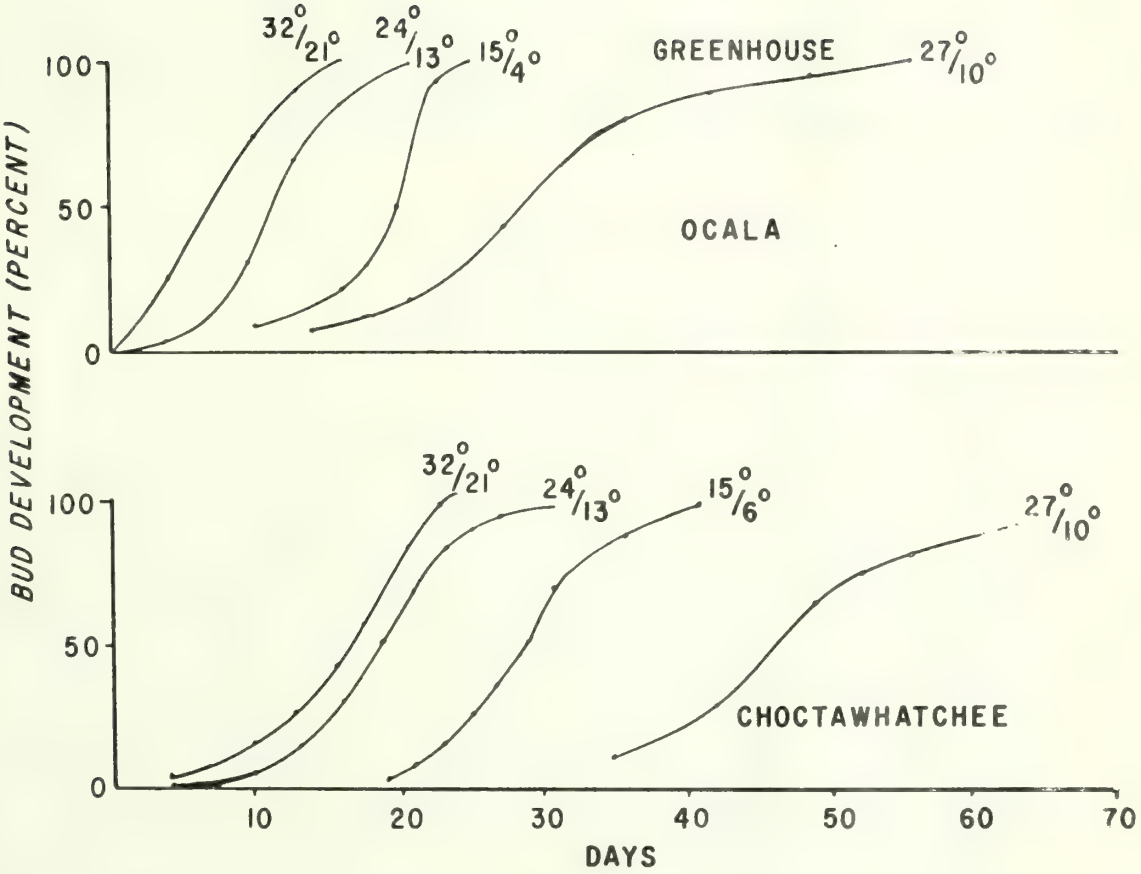

Figure 2. --Bud development under different temperature regimes.

METHODS AND GOALS IN PREPARING SAND PINE SITES

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Abstract.--Alternative methods of preparing sandhill land for sand pine are compared. Chopping, a method that conserves topsoil essential for plant growth in the sandhills, proved the most efficient of the mechanical methods and better than the chemical method considered. Because of inherently low site productivity, practical methods must be relatively inexpensive. If public pressures for environmental preservation and improved wildlife habitat are to be met, the natural landscape should be disturbed as little as possible during the conversion from scrub hardwoods to pine. Strip site preparation that conserves topsoil promises to meet these requirements. Choctawhatchee sand pine appears best suited for planting on partially prepared sandhill sites.

Mechanical site preparation is the most effective, hence the principal, method of site preparation used in the sandhills. Burning alone does not help seedlings survive and grow, and successive burns are difficult because fuels in the sandhills accumulate slowly and in patches. Chemicals are expensive, and until recently, did not result in satisfactory survival and growth of planted seedlings (3).

All methods of mechanical site preparation destroy the vegetation by cutting or displacing it. These processes destroy the aboveground portions of hardwoods and sever subsequent sprouts, thereby depleting food reserves stored in the roots. Roots may also be torn out of the soil or destroyed in the soil by being cut, chopped, moved, or exposed. Mechanical site preparation is most commonly done with choppers, rakes, disks, and rotary tillers--sometimes in combination.

The purpose of this paper is to review alternative methods of site preparation that have been used to establish pines in the sandhills, to compare results obtained with the various methods, and to explain why differences in survival and height of pines planted on variously prepared sites probably occur.

METHODS FOR ESTABLISHING SAND PINE PLANTATIONS

Underplanting and Release

All the southern pines planted in the sandhills with the exception of sand pine (Pinus clausa (Chapm.) Vasey) require intensive site preparation to ensure adequate survival. This preparation involves reducing the number and vigor of the scrub oaks (principally turkey oak, Quercus laevis Walt., and bluejack oak, Q. incana Bartr.) and wiregrass (Aristida stricta Michx.). Release from overtopping scrub hardwoods after underplanting is not enough for pines other than sand pine, as illustrated by the results of the following test.

Seedlings (1-0 stock) of five pine species were hand-planted 6 feet apart in 8-foot rows amid scrub hardwoods on a sandhill site. Some seedlings of each species were released from overtopping trees at the time of planting, some were never released, and the remainder were scheduled for release at 2-year intervals through age 5. By age 4, the planting of longleaf pine (P. palustris Mill.) was a complete failure and the performance of loblolly (P. taeda L.) and shortleaf (P. echinata Mill.) pines was so poor that these plantings were abandoned. At plantation age 5, the slash pine (P. elliottii Engelm.) did not look as if it would survive, so the release scheduled for age 5 was applied only to Ocala sand pine (P. clausa var. clausa Ward).

At plantation age 12 years, the sand pines released at planting averaged 33 feet tall and those released 1, 3, and 5 years after planting were 28 to 29 feet tall (table 1). Varying the time of release did not have an appreciable effect on growth among trees not released at the time of planting. Despite the competing hardwoods, unreleased Ocala sand pine averaged 26 feet tall--fully twice as tall as the slash pine released at the time of planting.

Table 1.--Average survival and growth of Ocala sand pines and slash pines at plantation age 12 years, according to time of release from scrub hardwoods

Pine species or variety and time of release	Survival	Growing space	Height	D.b.h.
	Percent	Sq. ft.	Ft.	In.
Ocala sand				
Released at:				
Planting	61.1	78.6	32.8	5.1
1 year	55.6	86.3	29.3	4.1
3 years	52.8	90.9	27.8	3.8
5 years	62.5	76.8	28.6	4.0
No release	59.7	80.4	26.0	3.6
Average	58.3	80.3	28.9	4.1
Slash				
Released at:				
Planting	43.1	111.4	12.9	2.0
1 year	52.8	90.9	10.9	1.5
3 years	39.6	121.2	8.9	1.2
No release	60.0	80.0	6.7	.6
Average	48.9	100.9	9.8	1.3

At about age 17, unreleased Ocala sand pine overtopped the hardwoods; within 3 years these pines showed signs of a height-growth response. At age 20, unreleased slash pine still had not overtopped its hardwood competitors.

This comparison clearly demonstrates that sand pine is superior to the other southern pines in its ability to survive and grow in a sandhill rough, even without release from overtopping hardwoods. Release applied within 5 years after planting was better than none at all, but it was not as beneficial as a release applied immediately after the sand pine was planted. Slash pines were able to survive underplanting and respond to release, but they were unable to develop to a merchantable pulpwood size even when released from overtopping hardwoods: at 20 years, height of the slash pines released at planting averaged barely 20 feet. The deeper sands (which comprise the more droughty sites) are better suited to sand pine than slash pine. If the sand overlies a layer of clay, thus making soil moisture levels more favorable, slash pine will reach merchantable size.

Mechanical Site Preparation

Rootraking.--A second study was installed on a site where the preparation was intensive. The results indicate the importance of thorough site preparation prior to planting southern pines.

Choctawhatchee sand pine (Pinus clausa var. immuginata Ward), longleaf, shortleaf, loblolly, slash, and Ocala sand pines were hand- and machine-planted at a 7- by 7-foot spacing on a sandhill site which had been cleared with a rootrake, then disk harrowed and leveled with a roadgrader. Most of the organic matter and topsoil was removed. Data collected at plantation ages 5 and 12 are summarized in table 2. Because no lasting significant differences attributable to method of planting were found, results from machine- and hand-plantings are combined.

Table 2.--Average survival and growth of pines planted on a sandhill site intensively prepared with a rootrake, disk harrow, and roadgrader

PLANTATION AGE 5 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
	Percent	Sq. ft.	Feet	In.
Ocala sand	60.9	80.5	9.3	--
Choctawhatchee sand	88.4	55.4	8.4	--
Longleaf[a]	27.6	177.5	2.0	--
Slash	90.9	53.9	7.2	--
Loblolly	88.4	55.4	4.8	--
Shortleaf	87.8	55.8	4.0	--

PLANTATION AGE 12 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
Ocala sand	55.4	88.5	29.8	4.0
Choctawhatchee sand	87.1	56.2	27.5	3.8
Longleaf[a]	13.9	352.5	14.4	3.2
Slash	86.5	56.6	16.1	2.5
Loblolly	81.5	60.1	9.4	1.5
Shortleaf	83.0	59.0	7.8	1.4

[a] Brown spot needle blight was not controlled.

First-year survival averaged 90 percent for all but longleaf and Ocala sand pines. Brown spot needle blight (Scirrhia acicola (Dearn.) Siggers), and presumably improper planting depth, contributed to the 45 percent survival of longleaf pine. An unknown disease, later identified as mushroom root rot (Clitocybe tabescens (Fr.) Bres.), probably contributed to the relatively low first-year survival (65 percent) of Ocala sand pine and to subsequent mortality (5). This endemic fungus, which spreads from infection centers via root contact, is known to be responsible for mortality averaging about 3/4 or 1 percent per year over the past years. The planting of Choctawhatchee sand pine, which averages only 2 feet shorter and 0.2 inch d.b.h. smaller than that of the Ocala variety, remains disease-free although within 25 feet of the infected Ocala variety. Despite the root rot, and quite possibly because of the additional growing space provided by mortality, Ocala sand pine has grown to be the largest of all the pines by plantation age 12.

Survival of slash, loblolly, and shortleaf pines declined less than 7 percent between plantation ages 5 and 12; however, their height and diameter growth does not compare with that of sand pine, although all have had a similar amount of growing space available to them. Similarly, growth of Ocala and Choctawhatchee sand pines exceeds that of longleaf pine even though the sand pines had less than one-third as much available growing space over the last 7 years.

These tests confirm that slash, loblolly, and shortleaf pines require intensive site preparation when planted in the sandhills. On the intensively prepared site, fifth-year survival of the three pines averaged approximately 90 percent. When underplanted and immediately released, survival of slash pine averaged 43 percent (table 1) and that of loblolly and shortleaf pines (not included in the table) averaged 39 percent. Release from overtopping woody competition was not sufficient. Survival of sand pine was not as poor as that of the others, and sand pine grew well whether released or not. A comparison of 12-year-old sand pine in tables 1 and 2 shows that they grew taller when underplanted and released (32.8 feet) than when planted on the rootraked site (29.8 feet) where much of the topsoil had been removed.

A characteristic effect of rootraking is evident in this study. When the site is prepared with a rootrake, all standing vegetation is removed from the planting site and deposited in windrows, but so is much of the topsoil. Consequently, trees near the windrows grow taller than those in the center of the rootraked area and the plantation develops a saucer-shaped crown profile. The importance of topsoil for the growth of slash pine has been demonstrated by Brendemuehl (2) in a pot test. The saucer-shaped crown profile is apparent in sand pine as well as slash pine, but not to as great a degree.

Chopping.--Tests with site-preparation equipment have shown that slash pine, and presumably other pines, grow faster on sandhill sites prepared with a duplex brush cutter (chopper) than with other equipment. The chopper leaves the topsoil in place, thereby conserving it, and incorporates the herbaceous and all but the largest woody vegetation into the surface soil, thereby increasing its organic content (virtually the only source of nutrients in sandhill soils).

In a third study involving intensive site preparation, we compared the performance of slash, longleaf, loblolly, and Choctawhatchee sand pines machine-planted 6 feet by 8 feet on a sandhill site prepared by double chopping. To obtain a truer measure of its potential, seedlings of longleaf pine were sprayed four times in the first 2 years after planting to control brown spot needle blight. Measurements taken at plantation ages 5 and 12 are summarized in table 3.

Table 3.--Average survival and growth of pines on a site prepared by double chopping

PLANTATION AGE 5 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
	Percent	Sq. ft.	Feet	In.
Choctawhatchee sand	98.7	48.6	11.2	--
Longleaf[a]	72.7	66.0	3.0	--
Slash	65.0	73.8	6.9	--
Loblolly	74.6	64.3	5.7	--

PLANTATION AGE 12 YEARS

Pine species or variety	Survival	Growing space	Height	D.b.h.
Choctawhatchee sand	98.7	48.6	32.4	4.4
Longleaf[a]	55.0	87.3	16.0	2.8
Slash	63.3[b]	75.8	19.6	3.1
Loblolly	67.8[b]	70.8	11.7	2.0

[a] Sprayed with Zinc Coposil (4 lb. per 50 gal. of water) to control brown spot needle blight (four semiannual sprayings at ages 1 and 2).

[b] Best estimate of survival: based upon survival before a fire and subsequent rate of mortality of unburned plots.

The performance of sand pine was exceptional. First-year survival averaged 98.7 percent, and no trees died over the subsequent 11 years. Choctawhatchee sand pine, with an average growing space of less than 49 square feet per tree, grew to a height of 32 feet and a diameter of 4.4 inches by plantation age 12.

It appears that the amount of topsoil left on a site after preparation affects pine growth more than it does survival, at least for slash and loblolly pines. For Choctawhatchee sand pine, the additional topsoil on the chopped site seems to have improved survival as well. However, the comparison is not entirely legitimate. The soils were similar, but the chopped and rootraked sites were 20 miles apart. However, comparable results were obtained in another test installed in a relatively small area where loblolly, shortleaf, and Choctawhatchee sand pines were hand-planted at a 7- by 9-foot spacing on both chopped and rootraked sites (table 4).

Table 4.--Average survival and growth of pines at plantation age 10 years on a site prepared by either a rootrake or a chopper

Pine species or variety and preparation	Survival	Growing space	Height	D.b.h.
	Percent	Sq. ft.	Feet	In.
Choctawhatchee sand				
Chopped	76.0	82.9	27.7	4.1
Rootraked	68.0	92.6	29.0	4.7
Loblolly				
Chopped	96.0	65.6	16.9	2.7
Rootraked	80.0	78.8	14.1	2.2
Shortleaf				
Chopped	96.0	65.6	14.6	2.8
Rootraked	92.0	68.5	12.1	2.2

Results varied with species and method of site preparation. At age 5, average survival for all pines was lower on rootraked than on chopped sites, yet height differences were negligible for all but Choctawhatchee sand pine, which was taller on the rootraked site. Although sand pine continued to grow at a faster rate there through age 10, loblolly and shortleaf pines grew faster on the chopped sites. Results from comparative plantings on chopped and rootraked sites suggest that the field performance of Choctawhatchee sand pine planted in the sandhills of northwest Florida may be affected considerably less than the other southern pines by method of site preparation or soil fertility as measured by quantity of topsoil.

Rotary tilling. --Rotary tillage was another type of mechanical site preparation tested in northwest Florida. Because the tiller is not as rugged as the rootrake or chopper, large obstacles must be avoided. It does a thorough job of digging up and chopping roots; no second treatment is needed; and small tracts can easily be prepared. Its very thoroughness may be a disadvantage. Rotary tilling reduces the organic matter to small-sized particles and fluffs up the soil, aerating it excessively. This aeration encourages the oxidation of the organic matter, thereby reducing the amount of this valuable soil component.

Strip tillage with the rotary tiller might have special use in preparing land for sand pine because partial preparation appears to be sufficient for this species. The machine can be maneuvered through the woods to avoid large trees, stumps, and clumps of smaller trees. Sand pine planted on such strips has no primary competition, and, because of sand pine's ability to tolerate shade and drought, it will overtop residual competition and maintain a relatively uniform rate of growth.

Chemical Methods

Hundreds of chemicals were tested for control of scrub hardwoods without success until the soil sterilant monuron (3-(p-chlorophenyl)-1, 1-dimethylurea) was used (7). High dosages killed all competing vegetation but were expensive and left a residue in the soil that lasted for several years. Pines planted 9 months after 20 pounds per acre of the active ingredient were applied suffered a mortality of 85 percent (6).

More recently developed chemicals are as effective in killing oaks and are not persistent. One of these is fenuron (3-phenyl-1, 1-dimethylurea), a chemical related to monuron. It is applied in the form of pellets containing 25 percent active ingredient. We applied 10, 20, and 30 pounds of fenuron pellets per acre in June, planted Choctawhatchee sand pine the following January, and 4 years later found that growth on the untreated plots was about half that on areas that received the heaviest treatment:

Treatment per acre	Height after 4 years
(Lb.)	(Ft.)
0	2.7
10	3.6
20	4.2
30	5.4

Fenuron is no longer available, but a successor, bromacil (5-bromo-3-sec-butyl-6-methyluracil), appears to be as effective (4). Tests of this chemical are planned.

Age 4 may be too early to draw firm conclusions, but a comparison of heights at this age among the sites prepared by the various methods may indicate potential differences. The following tabulation compares studies involving herbicides, chopping, rootraking, rotary tilling (4 by 40 inches), and release. Both varieties of sand pine are included so that a rough comparison with underplanting and release (used only with the Ocala variety) can be made:

	Fenuron	Chopping	Rootraking	Rotary tilling	Release
	(Height in feet at 4 years)				
Choctawhatchee	5.4	7.6	6.2	5.8	--
Ocala	--	--	6.8	5.9	4.3

Trees grew less on chemically than on mechanically treated sites. And for Ocala sand pine, and possibly for the Choctawhatchee variety, growth was better on the plots treated mechanically than on the released plots.

Chemical methods may be especially suitable for the establishment of sand pine plantations because this species can be established on sites from which only the hardwoods have been removed. This type of site preparation leaves lesser vegetation untouched, and, because the hardwoods are eliminated, there is a surge of growth of the herbaceous plants. The increase of competition from this source may account for differences between the chemical and mechanical treatments, but it is not as great a deterrent to sand pine as it would be to other southern pines.

Although growth is not as great on chemically controlled sites as on chopped or rootraked sites, even though chemical control is fully as expensive, there are advantages to this method. Growth on the fenuron-treated plots was twice that on the check plots. The site was not disturbed (topsoil and organic matter were left in place), and a large investment in heavy equipment was not required. For this reason, pelleted herbicides provide an alternative method for preparing farm woodlands and odd blocks of land for sand pine.

GOALS IN SITE PREPARATION

It may seem peculiar to devote part of this paper to goals; we know what we want--the establishment of a desirable species. Until recently, such silvicultural and economic requirements have been setting the pace in regeneration. Now, the enhancement of wildlife habitat and amenity values has begun to assume increasing prominence.

One way in which the needs of wildlife and its enthusiasts can be favored is by the alternation of planted land with strips of wild land (1). The "edge" thus created stimulates production of a variety of food and cover. Strip site preparation appears to be a promising way of creating the same effect, especially if we use methods less harmful to the organic components of the soil than rotary tilling.

Sand pine plantations may already offer more wildlife food than those of other southern pines. We have noticed quite a number of fox squirrel nests in our older plantings. The seed-storing habit of Ocala sand pine makes food available year-round. Both Ocala and Choctawhatchee sand pines offer dense foliage and limbiness that provide more cover and avenues of escape than are available in the rough and in stands of other pines.

When sand pine is planted, it is not necessary to remove all competing vegetation. Consequently, roadsides need not be completely prepared. Narrow strips parallel to the road can be prepared and planted, or sand pine can be planted directly in the scrub oaks, leaving them as a screen along the right-of-way. The ability of sand pine to grow in such a habitat means that a managed forest can be established without the blemish of thorough site preparation.

Uniform spacing in pine plantations is an effective means of producing equal growing space for each tree, but the uniformity of mechanical spacing is unnatural and offends an eye sensitive to natural beauty. The alternation of planted, prepared strips with strips of wild land will create a woodland more satisfying in this respect. The natural alternation of sites--creeks, branches, flatwoods, uplands--can be accentuated by restricting sand pine and strip site preparation for sand pine to only the most adverse sandhill sites.

CONCLUSIONS AND RECOMMENDATIONS

From the foregoing data and discussion, we conclude that a minimum investment should be made on the deep sands, the sites with the lowest potential. Strip site preparation recommends itself because it costs less than root-raking or chopping an entire area. Moreover, strips can be prepared by methods that will conserve the organic matter in the sand and preserve the natural diversity of hardwoods and pines.

Where small tracts or limited accessibility make machine work overly expensive and where there is no danger of contamination, herbicide pellets will do a good job of preparing a rough for sand pine. Because the major part of the cost of chemical control of vegetation is for the material, this method will become especially attractive if the price of the chemical drops.

Where appearances are especially critical, as along highways and in or near scenic areas, relatively narrow strips can be prepared parallel to the right-of-way and planted with sand pine. Where gradual conversion to a managed forest without violent modification of the present vegetation is desirable, sand pine can be planted in the rough and either not released at all or released only to that degree most suited to the overall objective.

LITERATURE CITED

1. Beckwith, S. L. 1967. Effect of site preparation on wildlife and vegetation in the sandhills of central Florida. Eighteenth Annu. Conf. Southeast. Assoc. Game & Fish Comm. Proc. 1964: 39-48.

2. Brendemuehl, R. H. 1967. Loss of topsoil slows slash pine seedling growth in Florida sandhills. South. For. Exp. Stn., USDA For. Serv. Res. Note SO-53, 4 pp.

3. Burns, R. M., and Hebb, E. A. 1972. Site preparation and reforestation of droughty, acid sands. USDA For. Serv. Agric. Handb. 426, 61 pp.

4. Peevy, F. A. 1971. Application date and dosage influence kill of hardwoods by soil application of bromacil, fenuron, and picloram. 24th Annu. Meet. South. Weed Sci. Soc. Proc.: 271-273.

5. Ross, E. W. 1970. Sand pine root rot — pathogen: *Clitocybe tabescens*. J. For. 68: 156-158.

6. Woods, F. W. 1955. Tests of CMU for forestry. For. Sci. 1: 240-243.

7. __________ 1959. Converting scrub oak sandhills to pine forests in Florida. J. For. 57: 117-119.

WINTER AND SUMMER PLANTING OF SAND PINE

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Abstract.--Present knowledge indicates that 1-0 sand pine seedlings are the best stock for field planting. They should be planted deeper than the root collar, preferably during the months of January or February. Dibble and machine planting are almost equally successful. Infertile, excessively drained areas within the sandhills region of Florida and Georgia are the recommended planting sites. Some information suggests that sand pine should not be planted in the Carolina sandhills, but a final decision cannot yet be made. Because high densities of Choctawhatchee sand pine result in reduced height growth, only 500 seedlings per acre are recommended for planting if a single-harvest cut is planned and 750 if a commercial thinning is planned. Because survival of Ocala sand pine is generally lower and less consistent, about 900 seedlings per acre should be planted and the decision about thinning should be delayed until the trees reach merchantability.

INTRODUCTION

The establishment of stands of sand pine (Pinus clausa (Chapm.) Vasey) by planting is a relatively new venture. The oldest known plantation is on the Eglin Air Force Reservation in northwest Florida (2). It was planted in 1938 with wilding stock of Choctawhatchee sand pine (CSP).

Cooper et al. (4) experimentally planted Ocala sand pine (OSP on the Ocala National Forest in central Florida during the early 1950's. They mentioned that OSP had been planted occasionally prior to 1950, but with little success.

These early plantings, plus the few others from about the same period, received little attention for many years. Now, however, the superiority of sand pine over other southern pines in producing pulpwood on droughty, infertile sites has been recognized (3). Consequently, over 6 million nursery seedlings of sand pine are being produced annually for planting on the sandhills of Florida and Georgia.

This paper presents the best information now available on how to plant sand pine during the normal winter planting season plus a report on summer planting trials. It does not cover nursery practices, storage of planting bales, site preparation, or choice of variety to plant on various sites, for these topics are discussed in other papers in this Symposium.

SELECTION OF PLANTING SITES

Sand pine occurs naturally on infertile, excessively drained sandy soils. To date, most plantings have been made on such soils: the Lakeland, Kershaw, and Lakewood soil series in northwest Florida; their hyperthermic counterparts Lake, Astatula, and Paola in central Florida; the Alaga series in Georgia; and Troup in South Carolina.

These sandhill soils severely test newly planted pines. Such sites can revert to drought conditions 2 weeks after a heavy rain, and, on cleared land, surface temperatures sometimes exceed 160° F. (1). Nevertheless, these are the recommended sites--in Florida, at least--for planting sand pine because it outperforms other southern pines on such sites. Early results of studies in the Georgia sandhills indicate sand pine may also be the preferred species for excessively drained sites there. Not enough plantings of sand pine have been made in South Carolina to make recommendations for that state. Cold damage to Ocala seedlings (6) and ice damage to trees of both varieties of sand pine (7) may be problems there.

Occasionally, both OSP and CSP can be found on relatively wet sites, but their yields on such sites are lower than those of other southern pines. Moreover, mortality and foliar discoloration of sand pine have been observed on normally well-drained sites that become saturated from abnormally heavy rainfall (Russell M. Burns, personal communication).

AGE AND SIZE OF PLANTING STOCK

One-year-old planting stock of sand pine is usually smaller than that of loblolly (Pinus taeda L.) or slash (P. elliottii Engelm.) pines. This relatively small size prompted Cooper et al. (4) to compare survival of standard 1-0 stock with that of 1½-0 and 2-0 stock planted on the Ocala National Forest in December 1955. Six months after planting, the 1-0 stock with 71 percent survival was far superior to the 1½-0 with 20 percent and to the 2-0 with 5 percent. Cooper et al. suggested that survival of planted seedlings was closely related to their ratios of top length to root length. At lifting, root length was equal to or greater than top length for the 1-0 seedlings but was less than two-thirds top length for the 1½-0 and 2-0 seedlings. During the study, care was taken to retain as much of the root system as possible during lifting.

This study indicates that standard 1-0 stock is better than older stock. Perhaps increasing the size of planting stock could be beneficial, but attaining this increase by simply leaving seedlings in the nursery bed for more than 1 year is not the right approach.

OPTIMUM PLANTING SEASON

In another planting trial conducted by Cooper et al. (4) on the Ocala National Forest, about 7,500 OSP seedlings were planted in both November and December of 1953. Six months later, the November plantings averaged 44 percent survival and the December plantings averaged 55 percent--a statistically significant difference.

Burns (unpublished data) lifted CSP and OSP seedlings in early January, late January, and early February of 1969 and stored them 1, 3, 5, and 8 days before machine planting them on unprepared and on double-chopped sandhill sites. At the end of the first growing season, there was little difference in survival among seedlings planted at different dates (table 1).

These two studies indicate that December planting is better than November planting and that early February planting is as good as January planting, but the results are not definitive in determining the optimum planting season. What other information is available that might be helpful?

Table 1.--Average survival one growing season after storing seedlings 1, 3, 5, or 8 days and then machine planting them in northwest Florida

Lifting date	Choctawhatchee sand pine		Ocala sand pine		Average
	Unprepared site	Chopped site	Unprepared site	Chopped site	
	- - - - - - - - - -	- - - - - - - - - -	Percent	- - - - - - - - - -	- - - - - - - - - -
January 8	93	96	79	84	88
January 22	93	97	84	94	92
February 5	89	96	87	96	92
Average	91	96	83	91	91

Within the range of sand pine, commercial tree planting is usually started when the winter rains begin in late November or early December and is stopped before vigorous top growth begins, usually sometime in March. Thus, the optimum season must lie within this period.

Cool temperatures and ample moisture increase the chances of survival for newly planted seedlings. Long-term averages from the U. S. Weather Bureau Stations within the sandhill regions show that December and January are the coolest months of the year, that average temperatures and average precipitation for these two months are nearly the same and that February is the third coolest month and has higher rainfall than December or January (tables 2 and 3). These data suggest that all three months are good for planting. December may be the poorest of the three, however, because soil moisture may be deficient as a result of low rainfall in November.

Another reason for not planting in December may be that nursery seedlings are not at their physiological best for planting until January. No data are available for sand pine, but Huberman (8) discovered that seedlings of loblolly, slash, longleaf (Pinus palustris Mill.), and shortleaf (P. echinata Mill.) pines continue to increase in dry weight in the nursery beds between the first week in December and the first week in January. He attributed much of that weight gain to accumulated food reserves and suggested that these reserves have an important favorable effect upon survival after planting.

Thus, present information suggests that January and February are the best months for planting sand pine.

SPACING OF PLANTINGS

In discussing the spacing of plantings, we need some information that will be discussed more thoroughly later in this Symposium, i.e., the desired number of trees to carry through the rotation. In order not to take too much from a later paper, we shall simply say that, if no thinning is planned, about 400 trees per acre at the end of the rotation are recommended and, if a thinning is planned, about 600 trees per acre should be present at age 20.

What initial spacings should result in these desired densities at harvest ages? According to Burns and Hebb (3), CSP will average about 85 percent survival 1 year after planting and about 80 percent survival 20 to 30 years later. Thus, they recommend an 8- by 11-foot spacing (495 seedlings per acre) when a single harvest is planned but a 7- by 8-foot spacing (778 seedlings per acre) when one commercial thinning is planned. Spacings need not be exactly these dimensions, but extreme rectangularity should be avoided so that trees are not crowded within rows while growing space between rows is not being utilized.

Table 2.--Long-term mean monthly temperatures in sandhill regions as averaged from data from a series of U. S. Weather Bureau Stations within that region

Sandhill region	Stations	November	December	January	February	March
	Number	$^{\circ}$F.				
Central Florida	15	66.5	61.9	61.1	62.7	66.3
Northwest Florida	5	59.7	54.7	54.3	56.4	61.0
Georgia	5	54.3	47.6	47.9	49.7	55.3
South Carolina	6	53.7	46.3	46.7	48.0	54.0

Table 3.--Long-term mean monthly precipitation in sandhill regions as averaged from data from a series of U. S. Weather Bureau Stations within that region

Sandhill region	Stations	November	December	January	February	March
	Number			Inches		
Central Florida	18	1.69	2.03	2.11	2.77	3.91
Northwest Florida	7	3.10	4.02	4.06	4.15	5.55
Georgia	8	2.51	4.01	3.68	4.27	4.99
South Carolina	6	2.65	3.38	3.15	4.60	4.14

Table 4. --Planting densities for sand pine as based upon plans for thinning and upon expected survival

Commercial thinning	Survival expected at age 20	Spacing of planting	Stems per acre at planting	Stems per acre at age 20		
				Surviving	Cut	Remaining
	CHOCTAWHATCHEE SAND PINE					
	Percent	Feet	- - - - - - - - - - - - - -	Number	- - - - - - - - - - -	
No	80	8 x 11	495	400	0	400
Probably	80	7 x 8	778	600	200-300	300-400
	OCALA SAND PINE					
Possibly	45-67	7 x 7	889	400-600	0-200	400

Should not initial densities be higher in order to offset the possibility of low survival? Burns and Hebb (3) think not. They state that the chances of unacceptable survival with CSP are slight and that planting more trees per acre would necessitate expensive precommercial thinning when survival is average or above. As evidence, they report that CSP planted at 5- by 5-foot spacing began to grow more slowly in height between plantation ages 5 and 8 than those in wider spacings and that those planted at 7- by 7-foot spacing began slower height growth between ages 12 and 15.

Ocala sand pine usually has poorer first-year survival than CSP, and because of its susceptibility to mushroom root rot (Clytocybe tabescens (Fr.) Bres.), it also has poorer subsequent survival (3). Because OSP is planted on the same or similar sites as CSP, it might also suffer growth decline at about the densities and ages as does CSP. These considerations indicate that OSP should be planted at about 900 seedlings per acre (5- by 10-, 7- by 7-, or 6- by 8-foot spacing). With such initial spacings, subsequent survival should be neither so high that precommercial thinning is necessary nor so low that a single-harvest rotation would be seriously understocked (table 4).

MACHINE PLANT OR DIBBLE PLANT?

Machine planting of sand pine can give acceptable survival (table 1). So can dibble planting (3) (table 5). In the one comparison of type of planting found in the literature (4), there was no significant difference in survival between machine-planted and dibble-planted OSP.

Table 5.--Survival of sand pine 5 years after dibble planting on sandhill sites in Florida, Georgia, and South Carolina[a]

Variety of sand pine	Northwest Florida	Central Georgia	South Carolina
		Percent	
Choctawhatchee	87	75	81
Ocala	61	34	60

[a] Extracted from tabular data in Burns and Hebb (3).

Perhaps some unprepared sites could be too rough for proper planting by machine. With that exception, machine and dibble plantings probably result in similar survival and growth of sand pine seedlings.

DEPTH OF PLANTING

No reports on comparisons of depth of planting for sand pine could be found in the literature, but studies with slash and loblolly pines show that either their survival or their growth is increased by deep planting on well-drained soils (5, 10, 12). These results do not necessarily mean that sand pine will benefit from deep planting, but they do suggest that sand pine should be deep-planted until studies prove otherwise.

Burns (personal correspondence) recommends planting sand pine deep enough to cover the hypocotyl and reports excellent survival and growth after sand pines were machine-planted so that only the bud and a few green needles protruded above the soil. He also points out that machine planters usually throw mini-ridges against each side of the planted seedlings and that these ridges eventually are blown or washed away, re-exposing much of the stem and needles.

SUMMER PLANTING TRIALS

In an effort to supplement the winter planting season in Florida, McGregor (9) and Schultz and Wilhite (11) lifted and planted actively growing, bare-rooted seedlings of slash pine during several summer rainy seasons. Survivals ranged from excellent to less than acceptable. In the summers of 1966 and 1967, the planting trials were expanded to include OSP (14). All sand pine seedlings were raised at the Florida Division of Forestry Nursery in Chiefland, Florida. With the exception of early sowing and summer lifting, standard nursery and baling procedures were followed.

For the first summer's trials, OSP seed were sown in nursery beds in November 1965. (A normal April sowing would not have produced seedlings large enough for summer lifting.) By late June of 1966, the seedlings were only about 4 inches tall, but, because with care they could be handled with little stem breakage, a series of 10 weekly plantings was begun.

For each planting, 2,500 seedlings were lifted, baled, and transported 80 miles to the Withlacoochee State Forest in central Florida on one day and machine-planted the next. The planting site was a double-chopped ridge of longleaf pine and scrub oaks on Lakeland sand. The seedlings were set at the root collar or slightly below it. (Deeper planting would have buried many seedlings, for they still averaged less than 6 inches tall at the final planting in late August.) The seedlings in all plantings began wilting a few minutes after planting, and considerable mortality was apparent a few weeks after planting. By January, survival was less than 5 percent for each planting

Rainfall for the 10-week planting period averaged 2.7 inches per week, about 0.6 inch above normal, and was well distributed--the lowest weekly total being 1.1 inches. Thus, the seedlings should not have suffered from inadequate soil moisture. Sand pine is intolerant of excessive soil moisture, but it seems unlikely that soil moisture was excessive on this deep-sand ridge with a water table several feet below the surface. That excessive moisture was not the problem was further evidenced by the very low survival of the longleaf pine seedlings planted alongside the sand pine, even though longleaf pine is apparently more tolerant of excessive moisture than sand pine.

Thus, soil moisture did not seem to be the problem. Furthermore, the seedlings were handled with care, and the time between lifting and planting was about as short as practicable. Finally, the choices of site and of site preparation were apparently satisfactory, because the ridge was successfully replanted to sand and longleaf pines the following winter without additional site preparation. This process of elimination indicated that the seedlings themselves wêre not suitable for summer planting and that their small size was a likely cause of planting failure.

Consequently, in preparation for the second summer's trials in 1967, OSP seed was again sown in November (1966), but the first of the 10 weekly plantings was in mid-July rather than in late June. Also, some OSP seedlings from an April 1966 sowing were left in the nursery beds to furnish 1½-0 stock for the 1967 summer plantings.

Another double-chopped ridge of longleaf pine and scrub oaks on Lakeland sand--this one near Ocala, Florida--was chosen for the 1967 plantings. Part of this ridge had been successfully planted to sand pine a few winters previously. As before, seedlings were lifted, baled, and transported (this time about 50 miles) on one day and planted the next. One thousand seedlings of each age group were dibble-planted on each of the ten planting dates. The younger seedlings were less than 6 inches tall throughout all lifting dates. The older seedlings averaged about 12 inches tall at the first lifting and 20 inches at the last lifting, and they appeared to have much larger tops in relation to their roots than did the younger seedlings. The younger seedlings were planted deep enough to cover the hypocotyl; the older seedlings were set 1 to 2 inches deeper than that.

As in the previous summer, the seedlings began wilting a few minutes after planting. The last survival count was made in late September--less than 2 weeks after the final planting date. Survival of the seedlings planted on the 10 dates ranged from 0 to 2 percent for the older stock and from 2 to 9 percent for the younger stock. Soil moisture seemed ample, just as it did in the first summer's trial. The area received 9.20 inches of rainfall in July, ½ inch below normal, and 10.75 inches in August, 2 inches above normal. Only 2.62 inches fell in September, 6 inches below normal. The latter drought was of little consequence, however, for the earlier plantings were failures before September 1.

The results of these studies indicate that the low survival of summer-planted OSP cannot be attributed to lifting, storing or planting techniques, or to rainfall. Perhaps newly planted OSP seedlings cannot survive the high summer temperatures of the surface soil on cleared sandhill sites; however, slash pine seedlings survived summer planting in scalped strips on a ridge of Lakeland sand which also supported native OSP (13).

The OSP seedlings in the summer planting trials were not graded (except that the very small ones were thrown out), and measurements to determine average heights were the only morphological measurements taken. However, the seedlings were lifted and planted weekly for 10 weeks, beginning with 7-, 8-, and 15-month-old stock. If there is a morphological grade that has acceptable survival in the field, it would seem that one of the 30 plantings would have contained enough seedlings of that grade to give a survival percentage greater than 9.

We have no further plans for summer planting trials of any species. Should someone else wish to try summer planting of sand pine, here are a few possible approaches:

1. Try CSP.

2. Try container planting.

3. Attempt to increase the size of seedling roots in relation to that of the tops by modified nursery techniques. Wrenching might be a possibility.

4. To avoid the extremely high surface temperatures of prepared sites, try planting under scrub oaks and then releasing the pines after they have become established.

RECOMMENDATIONS

Recommendations on nursery practices, bale storage, site preparation, and the choice of variety of sand pine to plant on various sites are presented in other papers of this Symposium. Recommendations on planting as condensed from the discussion in this paper are as follows:

1. Plant only on sandhills or other infertile, excessively drained sites where sand pine can be expected to outperform other southern pines.

2. Plant in January or February.

3. Plant about 750 seedlings of Choctawhatchee sand pine per acre if a thinning is planned and about 500 seedlings if no thinning is planned.

4. Plant about 900 seedlings of Ocala sand pine per acre because this variety has poorer survival than the Choctawhatchee variety.

5. Bury hypocotyl and possibly most of the epicotyl during planting.

LITERATURE CITED

1. Burns, R. M. 1968. Sand pine: A tree for west Florida's sandhills. J. For. 66: 561-562.

2. __________ and Brendemuehl, R. H. 1969. Yield of a Choctawhatchee sand pine plantation at age 28. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-103, 4 pp.

3. __________ and Hebb, E. A. 1972. Site preparation and reforestation of droughty, acid sands. USDA For. Serv. Agric. Handb. 426, 61 pp.

4. Cooper, R. W., Schopmeyer, C. W., and McGregor, W. H. D. 1959. Sand pine regeneration on the Ocala National Forest. U. S. Dep. Agric. Prod. Res. Rep. 30, 37 pp.

5. Harms, W. R. 1969. Deep planting of slash pine in the Carolina sandhills. J. For. 67: 160.

6. __________ 1969. Sand pine in the Georgia-Carolina sandhills: third-year performance. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-123, 3 pp.

7. Hebb, E. A. 1971. Resistance to ice damage--a consideration in reforestation. USDA For. Serv. Tree Plant. Notes 22(2): 24-25.

8. Huberman, M. A. 1940. Normal growth and development of southern pine seedlings in the nursery. Ecology 21: 323-334.

9. McGregor, W. H. D. 1965. Successful summer planting of slash pine. J. For. 63: 208-209.

10. Malac, B. F., and Johnson, J. W. 1957. Deep planting increases survival of slash pine on a sandy site. Union Bag-Camp Paper Corp., Woodland Res. Note 5, 2 pp.

11. Schultz, R. P., and Wilhite, L. P. 1967. Operational summer planting of slash pine. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-80, 3 pp.

12. Slocum, G. K., and Maki, T. E. 1956. Some effects of depth of planting upon loblolly pine in North Carolina Piedmont. J. For. 54: 21-25.

13. Wilhite, L. P. 1966. Summer planting of slash pine shows promise in Florida. Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-23, 8 pp.

14. ________ and Schultz, R. P. 1969. Summer plantings of sand and longleaf pines fail. USDA For. Serv. Tree Plant. Notes 20(1): 7.

DIRECT SEEDING SAND PINES IN THE SANDHILLS OF NORTHWEST FLORIDA

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Abstract.--Choctawhatchee and Ocala sand pines were seeded biweekly during 1966 and 1967 on a sandhill site in northwest Florida. The seed were repellent-coated and covered with $\frac{1}{4}$ inch of soil. Some seed and seedlings were lost to predators, especially mice and ants. The highest proportion of sound seed germinated and developed into seedlings when sowing was done during November, December, and the first half of January. Temperatures during the 10-week period immediately after planting appeared to govern germination and, ultimately, the success or failure of the seeding operation.

INTRODUCTION

Sand pines (Pinus clausa (Chapm.) Vasey) can be established on sandhill sites by row seeding or by broadcasting seed and covering them with soil, as with a cultipacker. Success requires that seeding be done during months of the year that promise the best chance for stand establishment. Cooper et al. (2) sowed seed of Ocala sand pine (Pinus clausa var. clausa Ward) in April, but germination was delayed until October. The objective of the present study was to determine which months of the year are best for direct seeding sand pines and to ascertain some of the factors affecting seedling establishment of soil-covered seeds in the sandhills of northwest Florida.

METHODS

The study was established in a randomized complete-block design on a typical sandhill site prepared by double chopping and harrowing. Each variety of sand pine was assigned six blocks, and each block contained 26 plots. At biweekly intervals during 1966, one plot in each of three blocks was sown to each variety of sand pine. The procedure was repeated on the remaining three blocks in 1967. This work was part of a larger study which included slash and longleaf pines; the complete study will be reported elsewhere. No statistical comparison was made between varieties of pines.

Seed of the Ocala variety were collected on the Ocala National Forest in 1963 and, because of Ocala sand pine's closed-cone characteristic, included some seed from the 1963, 1962, and 1961 seed years. Seed of Choctawhatchee sand pine (Pinus clausa var. immuginata Ward) were harvested in 1963 and 1964 on the Eglin Air Force Reservation in Okaloosa County, Florida. Seed of both varieties were stored at 20° F. until sown. None were stratified.

Both seed lots were winnowed until cutting tests revealed 95 percent filled seed. Each lot was then thoroughly mixed, divided into 54 portions of approximately 500 seed each, and stored in numbered packets until randomly chosen for planting at biweekly intervals during 1966 and 1967. Each packet of seed was coated with a formulation to repel seed predators just before sowing. The extra two packets of seed were used in germination tests conducted in the laboratory before planting started in 1966 and again after it was completed in 1968.

Each plot was split to afford two levels of protection from large predators. One-half had no protective cover, and the other half was covered with a wire cone made of hardware cloth with a $\frac{1}{4}$-inch mesh. All seed were planted $\frac{1}{4}$ inch deep in a grid pattern of approximately 1-inch spacing. The unprotected spots were planted with 100 seed each, but the protected spots were planted with only 37 seed because of limited space under the protective cones.

A count of newly germinated and established seedlings was made on each seed spot at intervals of 4, 6, 8, 10, 12, and 52 weeks after planting. Signs of activity by predators of seed and seedlings were noted at these times. Rainfall data were read from a gauge located on the study area. Air temperatures were recorded at the Chipola Experimental Forest Headquarters approximately 3 miles away.

RESULTS AND DISCUSSION

Field data were converted to tree percents to facilitate comparison of results from unprotected seed spots and spots protected with wire cones:

$$\text{Tree percent} = \frac{\text{No. seedlings alive}}{\text{No. of seed planted}} \times 100$$

Tree percent for each seed spot 52 weeks after seeding is shown in figures 1 and 2. The 52-week seedling counts integrate germination, mortality, and loss to predators occurring in the first year after seeding.

Most germination occurred in the first 3 months after seeding. However, many recently germinated seedlings were counted in the 52-week tally, especially among the Choctawhatchee sand pines. These seedlings grew from seed which had lain in the soil 8 to 10 months before germinating.

The germination tests in the laboratory showed no loss in germinability attributable to 2 years of cold storage. At both the beginning and end of this 2-year period, germination of seed of Ocala sand pine was 85 percent and that of seed of Choctawhatchee sand pine was 83 percent.

On one occasion, a 4-inch rain uncovered some recently sown seed.

The most successful seedings were those made in fall and winter. Seedling establishment of both varieties was depressed during spring and summer. Depression of seedling establishment during the warm season was evident from March through September of 1966 and 1967 and even during unseasonably warm weather in late January and February of 1967. Correlations were highly significant between tree percents and the daily highs for air temperatures as averaged over the 10-week period after each seeding. As temperatures increased from 65° to 90° F., tree percents decreased sharply (figures 3 and 4).

Light shade cast by the wire cones on seedlings in the protected spots may have had a beneficial effect, especially among the Ocala sand pines. During the summers of both 1966 and 1967, consistently more seedlings of the Ocala variety became established under cones than outside. Such consistency was lacking among the Choctawhatchee sand pines.

Droughts had less effect on seedling establishment than did temperatures. There were three droughts during the 2 years of seeding. The first, in the spring of 1966, lasted almost 7 weeks (March 15 through May 1). There were only five showers during this drought, totaling less than 1 inch of rain. Establishment from seedings during the summer after this drought was no better than establishment from seedings during the drought.. The second drought, in the spring of 1967, lasted 13 weeks (February 22 through May 22). Ten showers during this drought yielded less than 3 inches of rain.

Again, establishment was no better after the drought. The third drought came in the fall of 1967 (November 3 through December 10). During this $5\frac{1}{2}$-week drought, only 0.23 inch of rain fell from two showers. This fall drought failed to depress establishment during a season of favorable temperatures.

In the course of planting the seed and counting the seedlings, the activities of a number of predators of seed and seedlings were observed. Three oldfield mice (Peromyscus polionotus) were seen on the plots at the beginning of the study. Many small mouse diggings were seen, and seed integuments were occasionally found nearby in almost every month of the year. The little excavations left by mice indicated that they sensed exactly where to dig for each seed. Mice in this study consumed some seed before being deterred by the repellent coating. Birds left no signs but probably accounted for additional losses, especially during periods of migration.

As would be expected, loss of seed and seedlings to mice and birds was less on spots protected by wire cones than on open spots. The protective cones appeared to have been effective in preventing losses to mice and birds but not to ants. Several species of ants were active on the plots. Florida harvester ants (Pogonomyrmex badius Latreille) were observed cutting off and carrying away cotyledons of sand pine in March 1966, and there was evidence of missing cotyledons even in December. Seedlings usually survived the loss of a few cotyledons, but seedlings died when all their cotyledons were removed. Ants were never seen cutting off primary or secondary needles.

Eastern moles (Scalopus aquaticus) and southeastern pocket gophers (Geomys pinetis) were occasionally active throughout the year. They tunneled directly under a number of seed spots. It was not determined if their burrowing activity caused seedling losses. While seed spots were being prepared, pocket gopher tunnels were encountered almost anywhere one chose to dig. Pocket gophers pile considerable quantities of sand on the surface when tunneling, and a few seed spots were partly buried under such piles, causing the loss of some seedlings.

Choctawhatchee sand pine seed is mildly dormant (1). Because of this dormancy, it was not surprising to find many recently germinated seedlings of Choctawhatchee sand pine at the time of the 52-week tally, as well as seedlings 9 or 10 months old. Two weeks of cold stratification are recommended (1) for seed of Choctawhatchee sand pine.

The sharp drop in seedling establishment for the seeding conducted on December 20, 1966, on unprotected spots may have been due to heavy predation. The difference in establishment of Ocala sand pines on protected and unprotected spots for this date appears larger than any difference that might be attributable to possible benefits of shading alone. This explanation is supported by the fact that the Choctawhatchee variety, which did not seem to derive as much benefit from shading by the wire cones, also suffered a sharp drop in establishment on this seeding date.

Temperatures, though unanticipated, proved to be a more controlling influence on the establishment of sand pine than were moisture conditions on the study plots. Consequently, fall and winter seedings were more successful than spring and summer seedings.

The most active predators of seed and seedlings were the oldfield mice and Florida harvester ants. Despite predation, 40 to 60 percent or more of the seeds sown from November through mid-January produced seedlings.

CONCLUSIONS

The best time to seed sand pine in the sandhills of northwest Florida is during November, December, and the first half of January. Fully 40 percent of planted seed can be expected to produce seedlings within 1 year under conditions similar to those encountered in the 2 years of testing. Extending the planting season for seed to include October or February is a gamble; chances for failure are about equal to those for success. Soil moisture, as measured by rainfall, is adequate for seedling establishment throughout most of the year, but the high temperatures normally experienced between March and September depress germination.

LITERATURE CITED

1. Barnett, J. P., and McLemore, B. F. 1965. Cone and seed characteristics of sand pine. South. For. Exp. Stn., U. S. For. Serv. Res. Pap. SO-19, 13 pp.

2. Cooper, R. W., Schopmeyer, C. S., and McGregor, W. H. D. 1959. Sand pine regeneration on the Ocala National Forest. U. S. Dep. Agric. Prod. Res. Rep. 30, 37 pp.

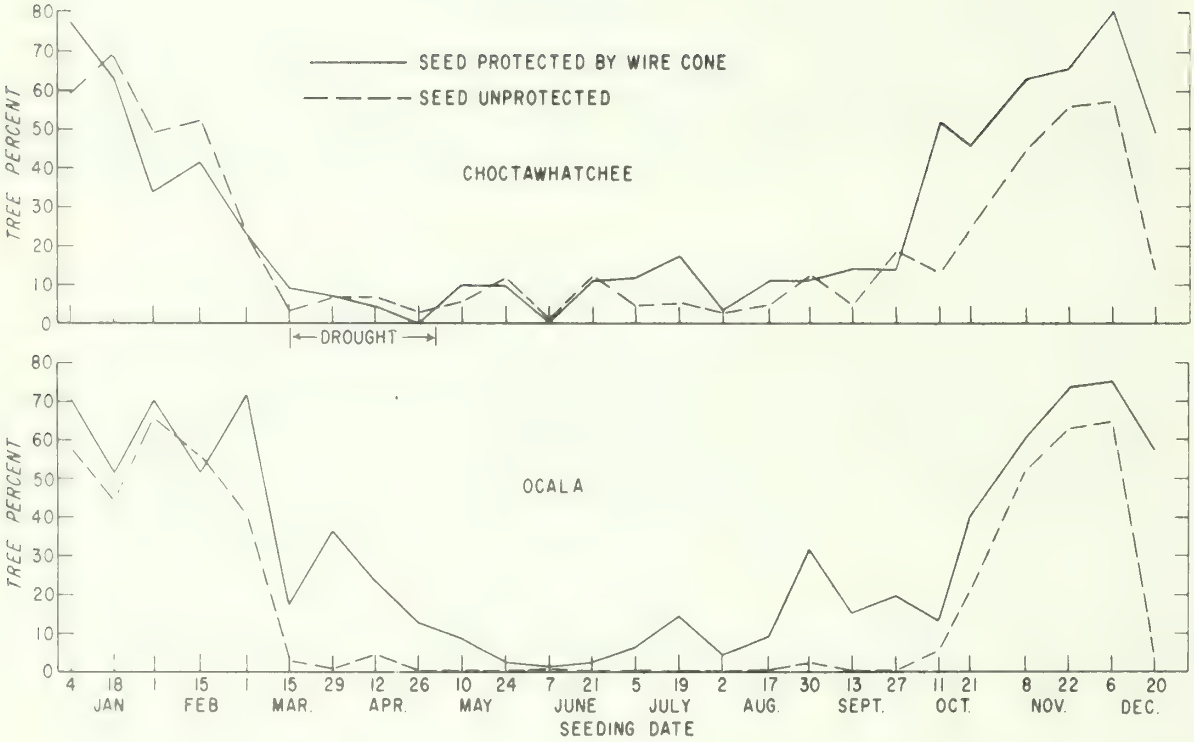

Figure 1. --Tree percents 52 weeks after the 1966 seedings of Choctawhatchee and Ocala sand pines.

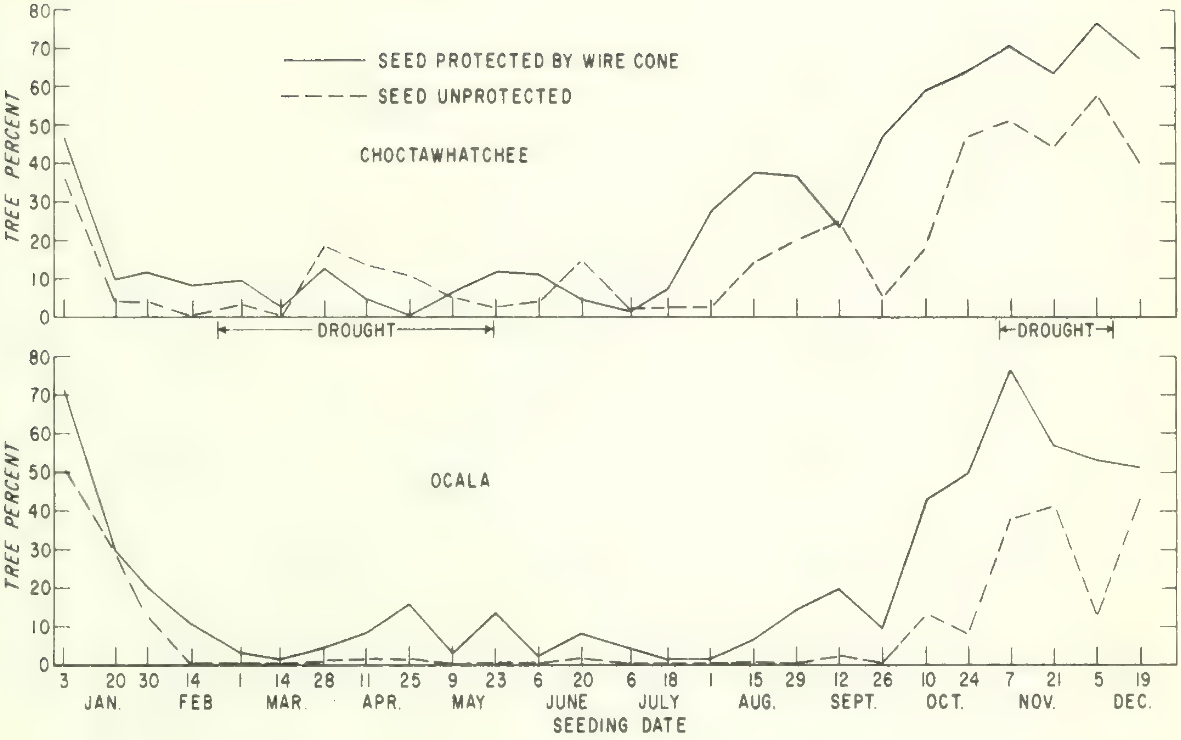

Figure 2.--Tree percents 52 weeks after the 1967 seedings of Choctawhatchee and Ocala sand pines.

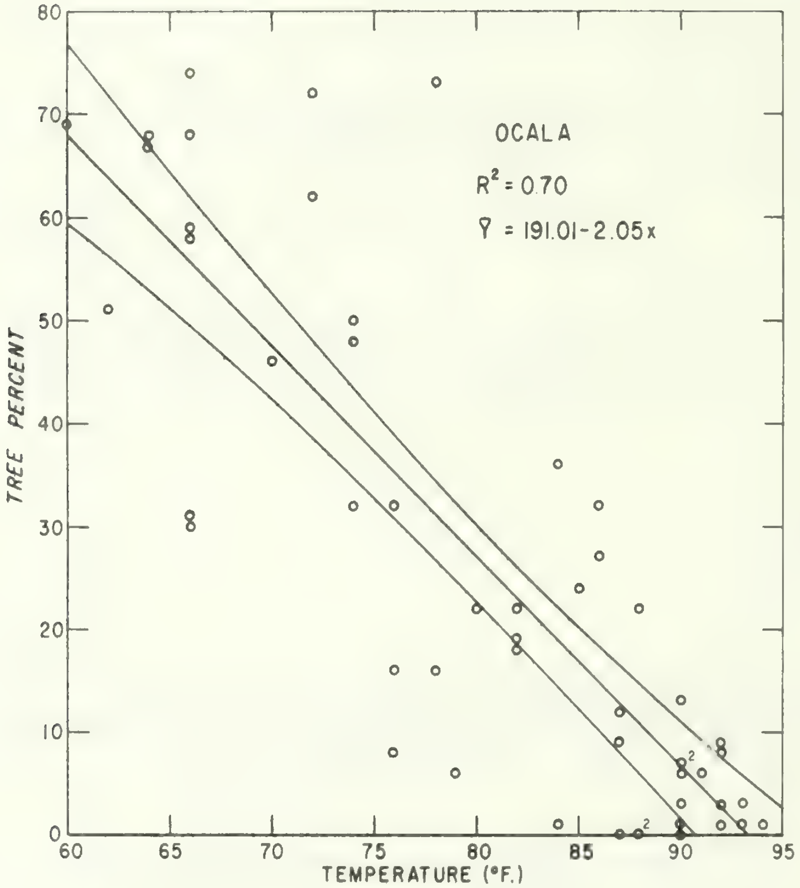

Figure 3. --Tree percents for Ocala sand pine at 10 weeks and average daily maximum temperatures during the 10 weeks after seeding.

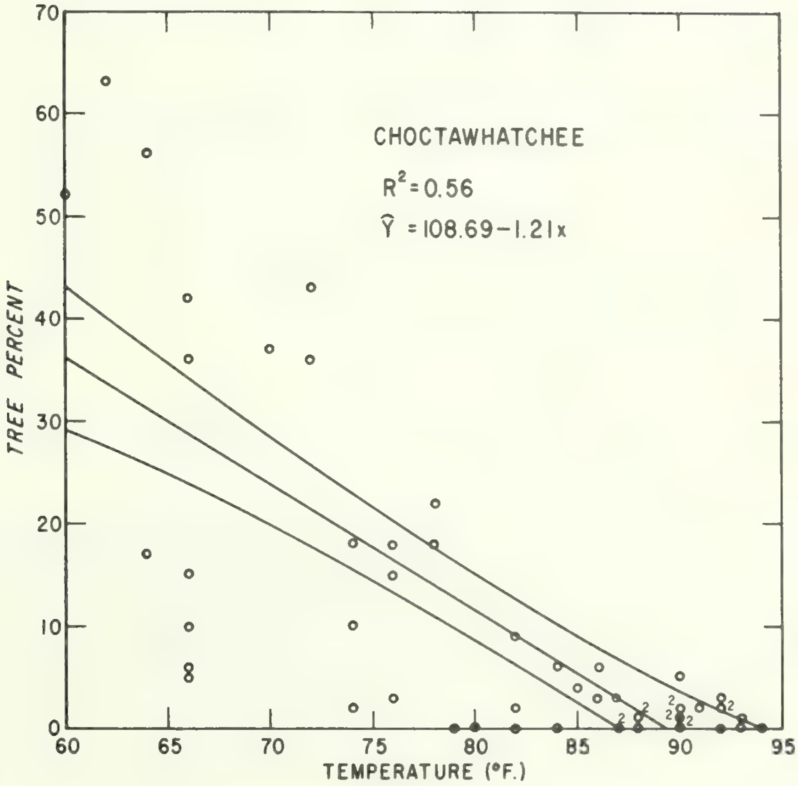

Figure 4.--Tree percents for Choctawhatchee sand pine at 10 weeks and average daily maximum temperatures during the 10 weeks after seeding.

COMPARATIVE GROWTH OF PLANTED AND SEEDED CHOCTAWHATCHEE SAND PINE

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Abstract.--Growth of 1-0 nursery stock of Choctawhatchee sand pine (*Pinus clausa* var. *immuginata* Ward) was hindered when planted amid year-old sand pines that had been direct-seeded, scrub hardwood sprouts, and vegetation that had invaded the previously prepared site. On newly prepared land, however, nursery stock initially grew faster than direct-seeded seedlings, though both were the same age from seed. During the ninth growing season, seeded pines grew slightly faster than planted nursery stock. Possible explanations are discussed.

INTRODUCTION

In the South, direct seeding and planting are commonly used methods of artificially regenerating pines. Sowing seeds directly in the field is cheaper than planting nursery-grown seedlings, but planted seedlings produce more uniformly stocked stands because planting is usually a more reliable method of reforestation. New and better seeding techniques and equipment are expected to correct many shortcomings of direct seeding. Whether direct-seeded pines, with the advantage of naturally developed root systems, grow as rapidly as planted nursery stock of good quality is not known. Experiments conducted in Okaloosa and Calhoun Counties, Florida, with Choctawhatchee sand pine (Pinus clausa var. immuginata Ward) were aimed at answering this question.

METHODS

Okaloosa County Planting

The study area was typical of many sandhill sites. Soils were well- to excessively drained sand underlain at depths of 84 to 108 inches with sandy loam material. The site was cleared of scrub hardwoods--mostly turkey oak (Quercus laevis Walt.) and bluejack oak (Quercus incana Bartr.)--and wiregrass--pineland threeawn (Aristida stricta Michx.)--by double chopping with an 8-ton duplex brush cutter. The first chopping was done early in October and the second in mid-November 1959. About 3 weeks later, repellent-coated seeds of Choctawhatchee sand pine collected in Walton County, Florida, in 1959 were either broadcast or row-seeded in plots established on the prepared site. Moderately dense to sparse seedling stands developed.

Seed from the same lot were sown in the Chipola Experimental Forest nursery in March 1960, 3 months after seeding the field plots. One year later, the 1-0 seedlings were lifted from the nursery bed and hand-planted among the year-old, direct-seeded seedlings. By this time, many of the scrub hardwoods had resprouted, and herbaceous weeds were invading the plots. Thirty to 40 planted seedlings and an equal number of the largest direct-seeded seedlings were identified with painted wire pins on each of six plots. Density on the plots averaged between 550 and 650 seedlings per acre. The height of these seedlings, approximately the same age from seed, was measured annually for 3 years and again at 5 years.

Calhoun County Plantings

The study in Calhoun County was on soil similar to that in Okaloosa County, i.e., sand underlain by a water-impeding layer of sandy loam or organic-coated sand at depths greater than 80 inches.

The study area was cleared of scrub hardwoods and wiregrass by burning in May and chopping twice with an 11-ton duplex brush cutter in early July and again in late August 1958. After chopping, the area lay fallow 4 years. In November 1962, one-half of the area was disked in preparation for seeding and planting in 1963. The remaining half was disked during November 1963 for a replicate installation in 1964.

Seed of Choctawhatchee sand pine were spot-seeded and seedlings were hand-planted in mid-February 1963 and in mid-February 1964. Seed for nursery sowing and direct seeding were from a composite seed lot collected in west Florida in 1961. Seedlings were 1-0 stock grown in the Chipola Experimental Forest nursery and were outplanted 1 day after lifting. Two rows, totaling 50 seed spots or seedlings, constituted a plot. Rows were 8 feet apart, and seedlings or seed spots within rows were at 8-foot intervals. At each seed spot, 12 repellent-coated seeds were planted $\frac{1}{4}$ inch deep and covered with a protective cone of hardware cloth. Seedlings were thinned to one per spot, and covers were removed after 1 year. Height of all seedlings was measured annually.

RESULTS

Okaloosa County Planting

In the Okaloosa County study, direct-seeded seedlings grew faster and were almost 2 feet taller than nursery transplants when both were 5 years old from seed (fig. 1, bars 1 and 2). The nursery seedlings grew faster only during the first year while they were in the nursery bed with the advantages of cultivation, fertilization, and irrigation. For the first 2 years after transplanting, seeded pines grew more than twice as much as the planted pines, and, although differences in growth rate decreased with time, the seeded pines continued to grow almost 25 percent more than planted pines during the fourth and fifth growing seasons.

Calhoun County Plantings

In the Calhoun County test, planted nursery stock grew faster; thus, these results were opposite from those obtained in Okaloosa County. Nursery stock in Calhoun County was 1.4 feet taller than direct-seeded pines when both were 5 years old from seed (fig. 1, bars 4 and 5). At 9 years from seed, the height differences had increased to 2.2 feet.

The amount by which nursery stock in Calhoun County outgrew direct-seeded pines the same age from seed increased each year to age 4 and declined after age 6. During the fourth, fifth, and sixth growing seasons, nursery stock grew 0.4 foot per year more than seeded pines the same age from seed. The difference decreased to 0.3 foot during the seventh and eighth growing seasons. During the ninth growing season, the trend reversed and direct-seeded pines grew 0.2 foot more than planted nursery stock.

Comparison of pines planted and direct-seeded the same year (i.e., nursery stock 1 year older than seeded pines but both having the same plantation age) is of interest from a practical standpoint. After 9 years in the field, nursery stock planted in 1963 averaged 6.6 feet taller than pines direct-seeded in 1963 (fig. 1, bars 3 and 4). Similarly, after 8 years, nursery stock planted in 1964 averaged 7.6 feet taller than pines direct-seeded in 1964 (fig. 1, bars 5 and 6). Clearly, through plantation age 9, planted sand pines in the Calhoun County study grew more than sand pines established by direct seeding.

When this comparison between nursery stock and seeded pines of the same plantation age is made, annual growth differences appear even greater than when pines the same age from seed are compared. The differences increased the first few years, peaked during the fourth and fifth years, and declined after that. In the 1963 installation, planted pines grew 1.6 feet more than direct-seeded pines during the fourth plantation year. During the ninth plantation year of the 1963 installation, both planted and direct-seeded pines grew at the same rate. In the 1964 installation, planted pines grew 1.5 feet more than direct-seeded pines during both the fourth and fifth plantation years. During the eighth plantation year, planted pines grew only 0.5 foot more than direct-seeded pines.

DISCUSSION

The direct-seeded seedlings outgrew the nursery transplants in Okaloosa County but did not in Calhoun County. The reason for this difference probably lies in part with the established vegetation on the ground in the Okaloosa County test at the time the nursery seedlings were transplanted. The newly transplanted 1-0 nursery seedlings had to compete with established year-old seedlings that had been direct-seeded, resprouting scrub hardwoods, and herbaceous regrowth. In contrast, direct seeding was done 3 weeks after the last chopping treatment so that most seeded seedlings had little vegetative competition.

The Okaloosa and the Calhoun County studies also differed in the season in which pine seeds were sown. Seeding in Okaloosa County was in early December, whereas the two seedings in Calhoun County were delayed until March. Fall germination of pine seed often occurs in nature and may have given the seeded seedlings in Okaloosa County a chance to establish deeper root systems than the seeded seedlings in Calhoun County. Well-rooted seedlings are better able to survive the severe moisture stress associated with spring droughts common to this area.

Still another difference between the Okaloosa and Calhoun studies was in the weight of choppers used for site preparation. The area in Calhoun County was chopped twice with an 11-ton brush cutter; hardwood sprouts and herbaceous vegetation were then disked just 3 months prior to planting and seeding. The area in Okaloosa County was chopped twice with an 8-ton brush cutter before direct seeding, but the seedlings were not planted until 1 year later. No additional site preparation was done in Okaloosa County in the interim. This delay permitted direct-seeded pines, invading herbaceous vegetation, and hardwood sprouts to become established. Comparative tests have shown that more and larger hardwood sprouts develop after chopping with an 8-ton brush cutter than with an 11-ton cutter.[1] Seedlings planted amid established competition rarely grow as rapidly as those introduced to a prepared site. The more intensive site preparation in Calhoun County provided less competition from herbaceous and woody vegetation than did the Okaloosa site. The fact that nursery stock in Calhoun County attained no more height in 5 years than nursery stock planted amid more competition in Okaloosa County indicates that either site or weather conditions were more favorable to pine growth in the Okaloosa County study.

In Calhoun County, nursery transplants outgrew direct-seeded pines in both the 1963 and 1964 installations. Vegetative competition was reduced equally for both sown and planted seedlings in this study. There is a biological explanation for this superior performance of the nursery transplants in the Calhoun County plots: they were fertilized and cultivated in the nursery for 1 year prior to outplanting. Nutrients incorporated in the seedling stimulate growth for several years after transplanting (1). With increasing age and mass, however, these nutrients are lost or are diluted so that they no longer stimulate growth. When this dilution occurs, the growth rate of planted seedlings approximates that of unfertilized direct-seeded seedlings. In the 1963 installation of the Calhoun County study, stimulating effects of nursery fertilization were no longer apparent after plantation age 8.

Direct-seeded trees retain a rooting advantage over transplanted trees, although this advantage may not become apparent for several years. Roots of planted stock are oriented in one plane by the planting slit and may develop abnormally when forced into a small hole (fig. 2, top). Improper planting may influence both survival and growth in later years. In contrast, roots of direct-seeded pines (fig. 2, bottom) are well distributed throughout the rooting zone, tap more of the soil's nutritive reserves, provide better support, and might be expected to develop more rapidly than root systems poorly planted in the same environment. Furthermore, planted seedlings initially have to recover from transplanting shock, whereas seeded seedlings do not. It takes time for the root system of a transplanted seedling to reestablish itself.

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[1] Burns, Russell M., and McReynolds, Robert D. Heavy vs. medium choppers for preparing sandhill sites for pine. (Submitted to USDA For. Serv. Tree Plant. Notes.)

CONCLUSIONS

When interplanted among year-old, direct-seeded seedlings and herbaceous regrowth, 1-0 seedlings of Choctawhatchee sand pine failed to grow as rapidly as their direct-seeded counterparts. When planted on newly cleared soils of deep sand, however, nursery transplants grew faster than direct-seeded seedlings, at least through plantation age 8. Differences in rates of height growth appear to decline with age, presumably because nutrients provided in the nursery are lost or diluted by tree volume. Indications are that the advantages of a well-distributed, naturally developed root system eventually may overbalance advantages of nursery care and fertilization, especially when roots of planted stock are poorly placed in the planting slit.

LITERATURE CITED

1. Switzer, G. L., and Nelson, L. E. 1967. Seedling quality strongly influenced by nursery soil management, Mississippi study shows. USDA For. Serv. Tree Plant. Notes 18(3): 5-14.

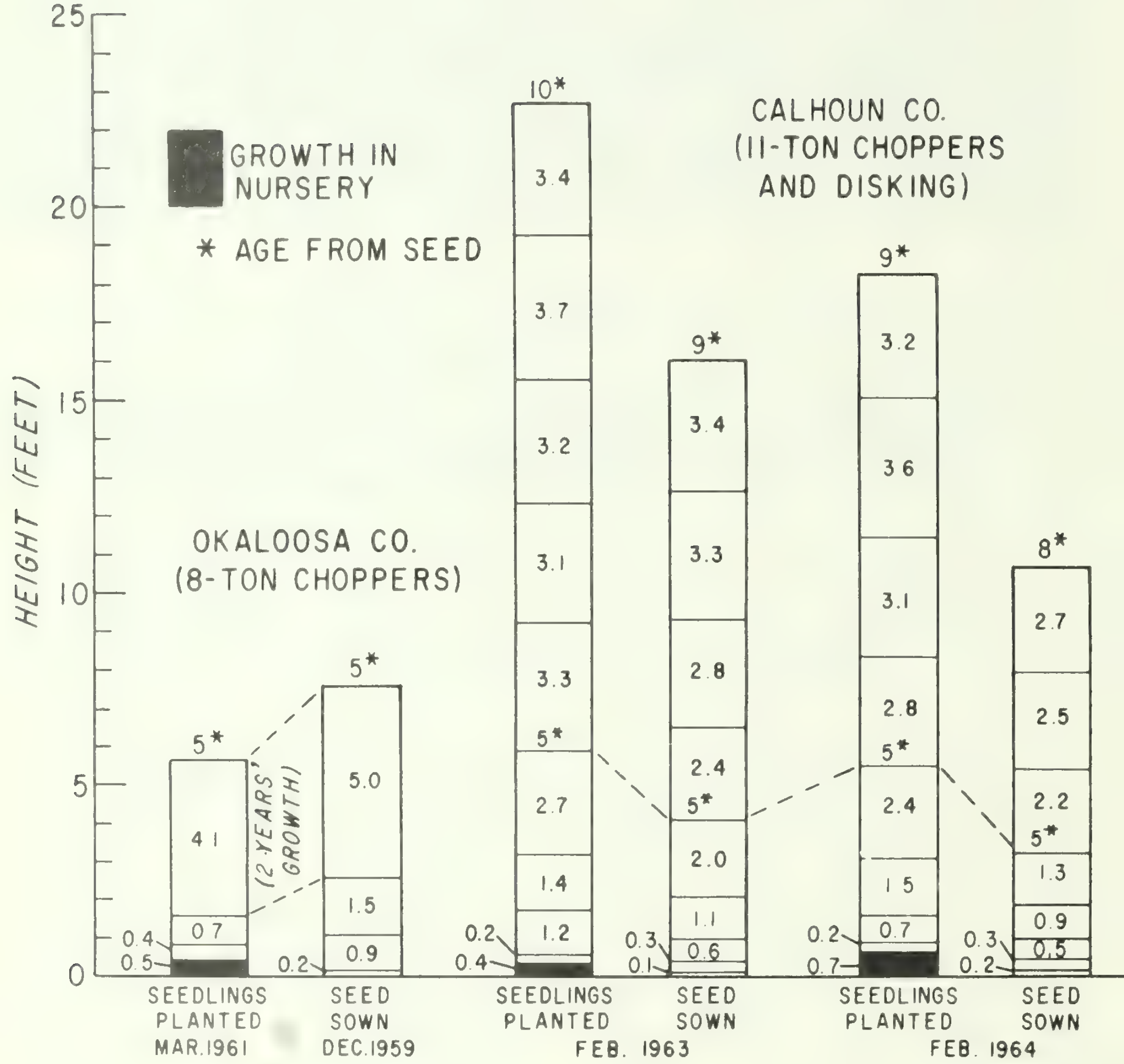

Figure 1. --Total and annual growth in feet of planted 1-0 seedling and direct-seeded Choctawhatchee sand pines. Bars 1 and 2 and bars 4 and 5 compare trees of equal age from seed. Bars 3 and 4 and bars 5 and 6 compare trees of equal plantation age.

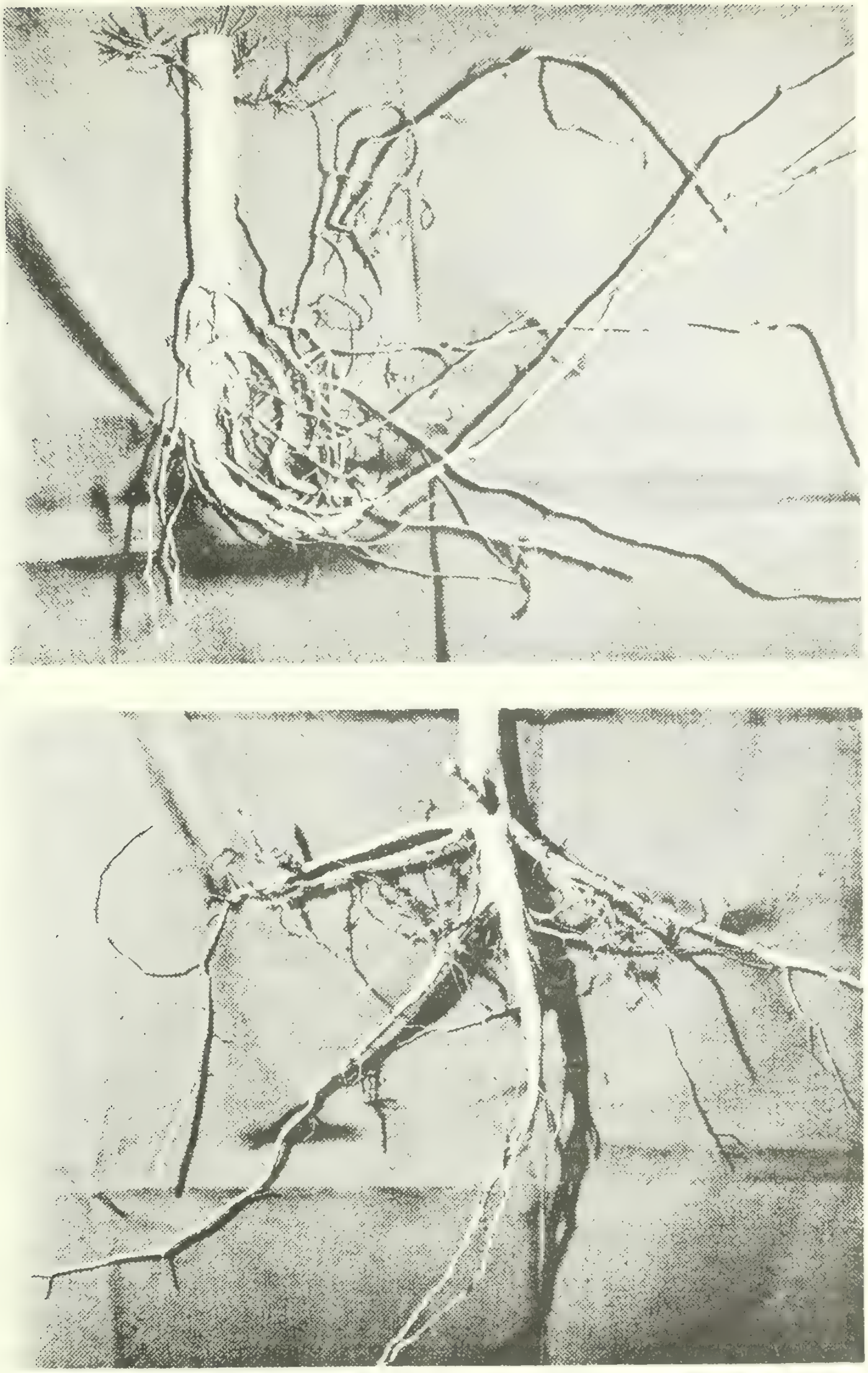

Figure 2.--(Top) Poorly planted seedling of sand pine. Because the roots were forced into a narrow planting slit, growth of the root system and of the entire tree may be retarded and the tree may not stand firm against the wind. (Bottom) Well-distributed root system of a direct-seeded sand pine. These roots will develop naturally and tap a larger volume of soil and its nutritive reserves.

COMPARATIVE GROWTH OF PLANTED PINES IN THE SANDHILLS OF FLORIDA, GEORGIA, AND SOUTH CAROLINA

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Abstract.--The performance of longleaf, slash, loblolly, shortleaf, and Ocala and Choctawhatchee sand pines was compared on several soils in the sandhills. Choctawhatchee sand pine appears best suited for planting on excessively drained sands in the Florida and Georgia sandhills and a good prospect for the Carolina sandhills.

This paper summarizes past and current research comparing the performance of native and exotic pines planted in the sandhills. Although data for several pines will be presented, particular emphasis has been placed on performance of sand pine (Pinus clausa (Chapm.) Vasey). Formal work with this species was initiated in Florida almost a decade before it was started elsewhere in the sandhills, and for this reason, most of the results presented here are from northwest Florida.

The adaptability of more than 40 conifers and several hardwoods from around the globe has been tested since formal research on regeneration started in the sandhills shortly before World War I. The majority failed. Some did not survive the nursery phase of the work. Others were not able to compete with established herbaceous and woody plants, to withstand the climate or, having survived planting, to sustain themselves in an alien and hostile environment.

Only five of the species tested show any promise. All are southern pines. All are well adapted to the climate, as evidenced by their performance on less refractory sites throughout the South. They are longleaf pine (*Pinus palustris* Mill.), slash pine (*P. elliottii* Engelm.), loblolly pine (*P. taeda* L.), shortleaf pine (*P. echinata* Mill.), and both the Ocala and Choctawhatchee varieties of sand pine (*P. clausa* var. *clausa* Ward and *P. clausa* var. *immuginata* Ward). Of these, only longleaf and sand pines are native on well- to excessively drained, infertile sandhill soils.

To obtain a clearer picture of comparative growth among species in the following tests, volume has been computed for both the average-size tree and for an acre.

The oldest comparative test of species on the Chipola Experimental Forest involved underplanting slash (SL), longleaf (LL), loblolly (LOB), shortleaf (SHTLF) and Ocala sand pines (OSP) at a density of 908 trees per acre and releasing them from overtopping hardwoods at various intervals following planting. Survival and height data were reported previously in this symposium by Hebb in a paper on site preparation. Reported here is a comparison of wood volume production for surviving SL and OSP at plantation ages 12 and 20 (table 1). Plantings of the other three pines failed.

When measured at age 12, the average OSP was 20 feet taller and 2¾ inches larger at d.b.h. than the average SL and had produced about 25 times as much wood. Unreleased OSP and SL growing at the same stocking level provided the most critical comparison. In this treatment, OSP were 19 feet taller and 3 inches larger at d.b.h. than SL and had produced more than 100 times as much wood per acre. Neither pine had as yet overtopped its hardwood competitors.

At age 20, the OSP plantings produced an average of 1,400 cubic feet of wood per acre. Trees released when planted produced at least half again as much wood (2,100 cubic feet per acre) as any of the other release treatments, and almost twice as much as unreleased OSP. By contrast, SL produced an average of only 64.4 cubic feet of wood per acre. Even the unreleased OSP produced almost 10 times the volume of wood produced by SL released at the time of planting. In every treatment, OSP attained a larger size than SL while growing with less available growing space per tree.

Differences in survival and, therefore, differences in stocking levels make a comparison of wood production on an average tree basis even more meaningful. In every release treatment, the average OSP produced from about 13 to 23 times more wood than the average SL. Unreleased OSP

Table 1.--Comparison of performance of slash and Ocala sand pine when underplanted and released

Treatment	Survival	Average height	Average d.b.h.	Volume[a]	
	Trees/ acre	Feet	Inches	Cu. ft./ tree	Cu. ft./ acre
PLANTATION AGE 12 YEARS					
Ocala sand pine:					
Released at planting	554	32.8	5.1	1.5646	866.8
Released at 1 year	505	29.3	4.1	.8905	449.7
Released at 3 years	516	27.8	3.8	.7463	385.1
No release	542	26.0	3.6	.6292	341.1
Average	529	29.0	4.2	.9649	510.7
Slash pine:					
Released at planting	391	12.9	2.0	.0948	37.1
Released at 1 year	479	10.9	1.5	.0469	22.4
Released at 3 years	479	8.9	1.2	.0250	12.0
No release	544	6.7	.6	.0048	2.6
Average	473	8.9	1.4	.0391	18.5
PLANTATION AGE 20 YEARS					
Ocala sand pine:					
Released at planting	542	45.8	6.9	3.9175	2123.3
Released at 1 year	505	40.8	6.0	2.6766	1351.7
Released at 3 years	516	40.5	5.6	2.2931	1183.2
No release	541	38.7	5.5	2.0953	1133.5
Average	526	41.5	6.0	2.7527	1447.9
Slash pine:					
Released at planting	391	19.7	2.9	.2953	115.5
Released at 1 year	466	17.0	2.4	.1725	80.4
Released at 3 years	479	14.9	1.9	.0990	47.4
No release	428	11.5	1.3	.0337	14.4
Average	441	14.8	1.9	.1461	64.4

[a] Total tree volume (conical volume) = 0.001818 x d.b.h.^{2} x height = cubic feet.

overtopped their hardwood competitors at about age 17, but SL had not done so by age 20. For this reason it is not too surprising that unreleased OSP produced more than 60 times as much wood on an individual tree basis as unreleased SL, and seven times more than SL released at the time of planting.

This comparison shows that both SL and OSP can survive underplanting with or without release from overtopping hardwoods, but that of the two, only sand pine will grow at an acceptable rate when underplanted in the sandhills.

Comparable results were obtained on intensively prepared sites. In one test, SL, LL, LOB, SHTLF, OSP, and Choctawhatchee sand pine (CSP) were planted at a density of 889 trees per acre. Results, summarized at plantation age 15 (table 2), show that the sand pines produced far more wood than other southern pines, and because of differences in survival, CSP produced more wood per acre than OSP. They also emphasize the influence that diseases have on pine survival and growth, and the importance of site preparation for pines other than sand pine planted in the sandhills.

The sand pines produced more than twice the volume of wood on an average tree basis as did any of the other southern pines. Of the sand pines, OSP produced about ⅛ cubic foot more wood than CSP. Volume production, however, is a function of the number of trees per acre as well as individual tree size: in plantations established at comparable spacings, factors affecting survival and growth influence wood production. Diseases play such a role in droughty, infertile sandhill soils.

Table 2.--Comparison of pine performance at plantation age 15 years on an intensively prepared sandhill site

Pine	Survival	Average height	Average d.b.h.	Volume[a]	
	Trees/acre	Feet	Inches	Cu. ft./tree	Cu. ft./acre
Ocala sand	481	36.5	4.4	1.2861	618.6
Choctawhatchee sand	771	34.6	4.2	1.1352	875.0
Longleaf	119	18.0	3.7	.4502	53.6
Slash	760	17.7	2.6	.2240	170.3
Loblolly	677	10.5	1.6	.0515	34.8
Shortleaf	706	8.5	1.6	.0379	26.8

[a] Total tree volume (conical volume) = $0.001818 \times \text{d.b.h.}^2 \times \text{height}$ = cubic feet.

The incidence of disease and pine survival and growth in this test were fairly typical for plantings on prepared sandhill sites in northwest Florida. Because of high planting density, stocking levels for most pines were higher than the 400 to 450 trees per acre believed to be optimum for pulpwood in the sandhills. CSP, growing under relatively crowded conditions, were almost as large as OSP. The difference in stocking levels resulted from the loss of OSP to mushroom root rot (Clitocybe tabescens (Fr.) Bres.). This loss enabled 771 CSP per acre to produce about 40 percent more wood than the 481 OSP. Slash pine growing at about the same density as CSP (760 per acre) produced only one-sixth as much wood.

The importance of site preparation for pines other than sand pine is demonstrated by a comparison of volume production for OSP and SL at age 15 in both tests. Interpolation of data in the first test indicates that 528 OSP per acre were alive at age 15, and that they averaged 34.2 feet tall and 4.81 inches in diameter. Similar computations show that about 454 SL per acre were alive and that they averaged 11.1 feet tall and 1.58 inches at d.b.h. Thus, 528 underplanted OSP produced 1.44 cubic feet of wood per tree and 760 cubic feet per acre, while 481 OSP planted on an intensively prepared site produced 1.29 cubic feet of wood per tree and 619 cubic feet per acre--a like amount on both sites. In contrast, 454 SL produced an average of 0.05 cubic foot of wood per tree and 23 cubic feet per acre when underplanted, while 760 SL produced an average of 0.22 cubic foot of wood per tree and 170 cubic feet per acre after 15 years of growth on the intensively prepared area. Clearly, OSP does not require intensive site preparation but benefits from release from overtopping competition, whereas SL needs intensive site preparation in order to survive and grow in the sandhills, albeit at a less than satisfactory rate. Supplementary informal tests conducted elsewhere in the sandhills show that CSP also survives underplanting and will overtop a scrub hardwood canopy at about the same age as OSP.

The second comparison on an intensively prepared sandhill site involved CSP, SL, LL, and LOB planted at a density of 908 trees per acre. In this test, brown spot needle blight (Scirrhia acicola (Dearn.) Siggers) on LL was controlled for 2 years following planting to obtain a measure of the species potential in the sandhills. Measurements taken at plantation age 10 (table 3) confirm results of the previous test on a prepared site and show that, even with some control of brown spot, growth of LL falls far short of CSP.

The effects of brown spot control for even 2 years are readily apparent. At age 5, almost three-fourths of the planted trees were alive and many had started height growth. About 14 percent of the LL died between ages 5 and 10. However, most of these trees were infected with brown spot and failed to escape the grass stage. Some of these trees probably could have been saved by prescribed burning because, by age 5, sufficient fuel had accumulated on the chopped site to sustain a fire. Fire was not used, however, so by age 10 LL stocking dropped to about 530 trees per acre. By sandhill standards, the site planted to LL may have been overstocked at age 10.

Table 3.--Comparison of pine performance at plantation age 10 years on an intensively prepared site in the west Florida sandhills

Pine	Survival	Average height	Average d.b.h.	Volume[a/]	
	Trees/ acre	Feet	Inches	Cu. ft. / tree	Cu. ft. / acre
Choctawhatchee sand	896	26.2	3.8	0.6959	623.3
Longleaf[b/]	529	11.4	2.3	.1137	60.2
Slash	555	15.9	2.6	.2032	112.7
Loblolly	625	10.2	1.6	.0500	31.3

[a/] Total tree volume (conical volume) = $0.001818 \times \text{d.b.h.}^2 \times \text{height}$ = cubic feet.

[b/] Sprayed with Zinc Coposil to control brown spot needle blight (four semiannual treatments at ages 1 and 2).

CSP produced twice as much wood on an average tree basis and three times as much wood on an acre basis at age 10 as LL, SL, and LOB combined. SL, growing at about the same stocking level as LL, produced twice as much wood as LL. However, if performance on the older test reported previously can be used as a guide, growth of LL will surpass that of SL within the next few years and may eventually produce a comparable amount of wood. Growth of neither SL nor LL is expected to approximate that of CSP within a 25- to 40-year pulpwood rotation. LOB appears to be a poor choice for Florida sandhills.

Species comparisons that include sand pine are quite rare in the sandhills of Georgia and the Carolinas. McGee (5) reported results of a test on Lakeland soil in South Carolina in which survival of planted CSP was 71 percent, but tree height averaged only 1.9 feet at age 5. Improper planting is suspected as a possible cause of the poor growth. Sand pines planted in the sandhills at the conventional root-collar depth, or shallower, seldom survive and grow as well as those planted deep enough to insure that the lowest whorl of green branches remains covered with soil.

The poor height growth cited by McGee should have been sufficient to discourage further testing of sand pine so far north of its natural range, but fortunately it was not. That year, comparative plantings including both varieties of sand pine were installed on an Alaga loamy sand in Georgia and on a Troup loamy sand in South Carolina (2). Results of the test indicate that sand pine will survive climatic extremes not normally encountered within its native range, and that relatively slight differences in fertility and depth of sandhill soils can markedly influence the field performance of planted pines.

The test site in Georgia was prepared with a bulldozer with the blade set at the soil surface. In South Carolina the site was root-raked, disked, and cropped for watermelons the year prior to planting. OSP, CSP, LL, SL, and LOB seedlings were planted at a density of 1,210 trees per acre on both areas. No attempt was made to control brown spot needle blight. When the plantations were 5 years old, a severe ice storm struck the South Carolina planting (3). During their seventh growing season, trees on both sites were thinned to standardize stocking levels among pines: the Georgia plantings to 463 and the South Carolina plantings to 649 trees per acre. Diseased, damaged, and poorly formed trees were preferentially removed to meet required stocking levels and to obtain uniform distribution of residual trees. Original stocking levels were high enough for all but LL in Georgia so that only the best trees were left. Measurements taken at plantation ages 5 and 7 are summarized in tables 4 and 5.

Few trees died after the first year. Wilted planting stock was blamed for low LL survival, and a freezing temperature shortly after planting was blamed for OSP mortality (2). Survival of CSP averaged 76 percent in Georgia and 82 percent in South Carolina at age 3. Survival of SL and LOB averaged 85 to 97 percent on both sites.

The paucity of nutrients in sandhill soils usually is reflected in the growth of planted pines within 3 to 6 years. Differences manifest themselves earliest on the poorest sites and among the most poorly adapted species. In these tests, CSP was slightly taller than SL or LOB at age 3 in Georgia and by age 5 in South Carolina. By age 7, following the thinning, CSP was clearly taller and larger than any of the other pines in Georgia and South Carolina.

All pines survived and grew better on Troup loamy sand in South Carolina than on Alaga loamy sand in Georgia. Differences were attributed to a greater store of moisture available for tree growth and to fertilizer residues from the watermelon crop previously grown on the South Carolina site (1).

In the Troup loamy sand, an argillic horizon at about 4 feet retained moisture at a depth inhabited by pine roots. In comparison, the fine-textured horizon in the Alaga loamy sand in Georgia was at too great a depth to materially influence survival and growth of the young pines. Chemical analyses of the two soils also revealed evidence of calcium and phosphorus at the 4- to 12-inch depth in Troup loamy sand where the watermelons had been grown. In most sandhill soils, pines do not respond to other nutrients until a phosphorus deficiency is satisfied.

All pines in the South Carolina test were damaged by ice to some degree, but damage appeared to be greatest in sparsely stocked stands of tall trees. OSP suffered most (37 percent damaged), LOB least (13 percent damaged), and SL, CSP, and LL suffered an intermediate amount: 27, 25, and 23 percent, respectively. Because the CSP planting was taller and more widely spaced than the SL planting yet suffered no more damage, CSP appears to be better suited for planting in the sandhills of South Carolina than SL. Both were planted north of their natural ranges.

Table 4.--Pine performance in Georgia

PLANTATION AGE 5 YEARS

Pine	Survival	Average height	Average d.b.h.	Volume[a/]	
	Trees/ acre	Feet	Inches	Cu. ft./ tree	Cu. ft./ acre
Ocala sand	417	7.8	1.0	0.0134	5.6
Choctawhatchee sand	905	8.3	1.0	.0148	13.4
Longleaf	195	1.5	1.1	.0036	.7
Slash	1015	5.1	.8	.0064	6.5
Loblolly	1061	5.4	.7	.0054	5.7
PLANTATION AGE 7 YEARS[b/]					
Ocala sand	415	13.9	2.2	.1176	48.8
Choctawhatchee sand	357	14.5	2.2	.1278	45.6
Longleaf	312	4.8	1.5	.0195	6.1
Slash	460	9.6	1.6	.0418	19.2
Loblolly	415	9.7	1.4	.0365	15.2

[a/] Total tree volume (conical volume) = 0.001818 x d.b.h.^{2} x height = cubic feet.

[b/] Sample size increased, and trees thinned to leave 463 per acre. (Longleaf was the only pine that did not meet this minimum stocking level.)

Table 5.--Pine performance in South Carolina

Pine	Survival	Average height	Average d.b.h.	Volume[a]	
	Trees/ acre	Feet	Inches	Cu. ft./ tree	Cu. ft./ acre
PLANTATION AGE 5 YEARS					
Ocala sand	724	9.7	1.2	0.0262	19.0
Choctawhatchee sand	980	10.6	1.4	.0357	35.0
Longleaf	713	5.8	1.3	.0184	13.1
Slash	1108	8.8	1.5	.0363	40.2
Loblolly	1158	10.0	1.5	.0386	44.7
PLANTATION AGE 7 YEARS[b]					
Ocala sand	649	15.0	2.4	.1555	100.8
Choctawhatchee sand	563	15.8	2.5	.1814	102.0
Longleaf	649	10.3	2.1	.0805	52.2
Slash	649	13.2	2.3	.1317	85.4
Loblolly	645	13.5	2.2	.1164	75.0

[a] Total tree volume (conical volume) = 0.001818 x d.b.h.^{2} x height = cubic feet.

[b] Sample size increased, and trees thinned to leave 649 per acre.

The thinning was scheduled for the hottest summer month to reduce the likelihood of infection by Fomes root rot (Fomes annosus (Fr.) Karst.). No evidence of annosus was found, but bark beetles (Ips spp.) attracted by the thinnings attacked all pines. However, their attack seemed directed at CSP.

Interpretation of results of these tests is confounded by differences in stocking levels through age 6, the ice damage in South Carolina, and the preferential insect attack following the summer thinning. Prior to thinning in Georgia, the average sand pine tree had produced about twice as much wood as other species, and CSP had produced twice as much wood per acre as other pines. Following the thinning and the insect attack, the remaining 357 CSP and 415 OSP had produced from about 2$\frac{1}{3}$ to 9 times more wood per acre than 312 LL, 460 SL, or 415 LOB. The average CSP manufactured slightly more wood during the 7 years than OSP. Before the ice storm, LOB and SL growing at a higher stocking level were shorter but larger in diameter than CSP. They also produced more wood. After the ice storm, thinning, and insect attack, the 563 CSP remaining at age 7 had produced more wood on an average-size-tree basis and on an acre basis than other pines growing at a density of at least 80 stems more per acre.

The performance of sand pine in another comparison in the Georgia sandhills elicited a recommendation from Keider (4) for planting sand pine rather than slash pine on deep sandy soils of the Fall Line. Measurements taken during the thirteenth growing season showed that slash pines at a density of about 400 trees per acre had attained a size of 17 feet and 2.8 inches d.b.h. In contrast, Ocala sand pine growing at a density of 310 trees per acre were 29 feet tall and 5.1 inches d.b.h. Implications from Keider's report and results from plantings installed by Harms suggest that CSP is a safe choice for the Georgia sandhills and a good prospect for the Carolina sandhills.

SUMMARY AND RECOMMENDATIONS

Sand pine will produce more wood in a shorter time than other pines planted on droughty sandhill soils. The species is tolerant of underplanting and responds to release. Neither intensive site preparation nor fertilization is required, but sand pine benefits from both. CSP is preferred over OSP because of its higher planting survival, apparent resistance to mushroom root rot, superior form, and greater tolerance to freezing temperatures.

Shallow planting is believed responsible for poor survival and growth occasionally reported for CSP in the sandhills. Seedlings should be planted deep enough to insure that the entire hypocotyl remains underground after the soil settles--at least the lowest whorl of green branches should be planted.

Summer thinning of CSP should be avoided. In Georgia and South Carolina, bark beetles preferred CSP over other pines planted. Planting at a spacing to obviate the need for any thinning, or thinning more closely planted trees during winter, seems a prudent alternative to thinning during the summer.

LITERATURE CITED

1. Burns, R. M. 1972. Choctawhatchee sand pine - good prospect for Georgia-Carolina sandhills. J. For. 70: 741-742.

2. Harms, W. R. 1969. Sand pine in the Georgia-Carolina sandhills: third-year performance. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-123, 3 pp.

3. Hebb, E. A. 1971. Resistance to ice damage--a consideration in reforestation. USDA For. Serv. Tree Plant. Notes 22(2): 24-25.

4. Keider, M. A. 1970. Sand pine on Georgia Fall Line sandhills. Georgia Kraft Co. Res. Note 20.

5. McGee, C. E. 1964. Species test in the sandhills. For. Farmer 24(2): 10, 15.

MANAGEMENT OF NATURAL STANDS OF CHOCTAWHATCHEE SAND PINE

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Abstract.--This paper describes the important factors that have influenced the formation of stands of Choctawhatchee sand pine, discusses the characteristics of the species, and explores some management dynamics and techniques used for natural stands of this species at Eglin Air Force Base in Florida. Opportunities for using Choctawhatchee sand pine for small-diameter forest products are compared with those for other southern pines.

The management of natural stands of Choctawhatchee sand pine is not a new topic for foresters--it has been around for quite some time. But there has been a change. The tone of discussion is now directed toward the question, "What are the opportunities ahead for sand pine?" This change has resulted because of one reason: the present and future concern for timber.

I will briefly describe the important factors that influenced the formation of stands of Choctawhatchee sand pine, discuss the characteristics of the species, and explore some management dynamics and techniques in natural stands.

For a quick review of the subject of managing natural stands of Choctawhatchee sand pine, we should look at the background. Back in the "good old days" when Eglin Air Force Base--a large 464,000-acre military base in northwest Florida--was known as the Choctawhatchee National Forest, sand pine was discussed in most meetings where management decisions were being made. The Forest Rangers of that day believed that "a stand of timber is only as good as the trees in it." Consequently, the discussions of managing sand pine usually ended in a gruff and nasty fashion. To put it simply, sand pine was considered to be worse than Bermuda grass in a cornfield--it was a weed! It grew and spread like a weed. Sand pine sprang up everywhere it was not wanted, particularly wherever a beautiful, tall, stately longleaf pine was cut and where it was expected to be replaced b another vigorous, shapely, young longleaf pine. The management of sand pine was simple: a crew of CCC boys were dispatched with sharp axes to do a "weeding" in accordance with the prescription-of-the-day. And that was the genesis of our present system of managing natural stands of Choctawhatchee sand pine.

DESCRIPTION OF THE TYPE

Now let us assess some of the factors that have influenced the formation of the natural stands of Choctawhatchee sand pine around Eglin Air Force Base. How did this forest develop? We cannot be sure, but observation provides some clues for an educated guess.

Eglin's forest lands are dominated by the longleaf-slash type. However, the virgin longleaf-slash pines that once were so abundant have gradually disappeared. Man has profoundly affected this plant community by his timber cutting, naval stores operations, and grazing practices. Yet man's greatest influence has been through the use of or exclusion of fire. These four practices have greatly affected the spread of Choctawhatchee sand pine into areas that it once did not occupy. Even though this spread has taken place in a relatively short period, it has resulted in Choctawhatchee sand pine's becoming the dominant species on about 100,000 acres of our cutover longleaf-slash land. To be more descriptive, this is a very large "land gra and represents almost 20 percent of our land holdings.

Most of the soils are deep sands of the Lakeland soil series. The soils tend to be infertile and low in organic matter. Altitude varies from sea level to 295 feet above sea level, and gentle hills characterize the terra The average site index is between 60 and 70 feet for sand pine. More than 2 percent of Eglin's soils is classified as being well-suited for growing sand pine, whereas 37 percent is classified for growing slash pine and 32 percen for growing longleaf pine. The rest is designated for hardwoods.

The sand pine type occurs over a wide variety of sites, from white beach sands to the best loamy sands. It tends to occupy the sandiest soils because its capacity to extract moisture and nutrients from these soils is superior to that of other southern pines. Of course, the best soils produce the faster growing, larger sized sand pines, whereas the white beach sands produce the "runts," the picturesque trees with the artistic, windswept crooks.

Sand pine usually grows in pure stands with heavy densities and is essentially single-storied. Frequently, the open-grown stands of sand pine are layered and multi-aged, with seedlings and saplings beneath the parent trees giving a multi-storied appearance.

The best development of sand pine takes place in stands with 1,000 to 1,500 stems per acre. Open-grown trees develop poor forms with large orchard-shaped crowns and many branches and often with crooked stems. On the poor sites, sand pine tends to form dense stands in which growth is slow and trees are spindly.

CHARACTERISTICS OF CHOCTAWHATCHEE SAND PINE

Choctawhatchee sand pine is often described as "scrub pine" by most of the local residents, particularly by those who have been in the "logwoods" all of their lives. It is with this description in mind that I want to show a different side of Choctawhatchee sand pine, a view that will become clearer as I expound upon the best characteristics of the tree and its potential.

The species has several distinct advantages that are important to recognize. One advantage has already been mentioned: its superior ability to extract moisture and nutrients from sandy soils.

Let me explore this advantage a little further by asking this question: "What would sand pine do with adequate moisture and nutrients?" or "What will it do on a good site?" Mentally compare these measurements with measurements of other pines that grow under natural conditions:

	Best sites	Good sites	Average sites
Diameter	24 inches	18 inches	14 inches
Height	80 feet	75 feet	60 feet

These are actual measurements of some individual trees of the same age class at Eglin. They are not the ordinary trees that are seen when one looks at sand pines, but they do represent a potential. Furthermore, figures such as these will lead us to certain questions concerning management decisions. For instance, could this species be suitable for plywood? or for sawtimber? These are distinct possibilities.

The second advantage of sand pine is its ability to put on an early growth spurt in the spring, as well as to have winter flushes of growth. These may amount to about 6 inches of height for each spurt. The first growth spurt takes place in March with the earliest warm days. Sand pine is the first tree to start the height-growth process in the spring. It has been rated as moderately intolerant, but in its early establishment it is rather tolerant of shade and competition. You may ask, "What advantage is this?" For one thing, it gets a jump on its neighbors, the hardwoods. Also, it is the first tree to draw upon the water that is stored in the soil during the winter. Both of these are big advantages from a management standpoint, especially when rain is deficient in the spring.

The second spurt takes place during the summer with the coming of thundershowers. Height growth varies considerably at this time, but another few inches are formed. It is important to remember that this is the period when summerwood is being added to the diameter of the tree. Total height growth averages as much as 2 feet annually, and some genetically superior trees may average 3 feet in height annually.

Diameter growth on some of the open-grown sand pines with orchard-shaped crowns will average about one-half to three-fourths of an inch in a year. Diameter growth on an average tree in a natural stand is similar to that of other pines; also, it varies considerably from site to site. In contrast to the major southern pines, actual growth data for sand pine are relatively scarce, but yields of 40 cords to the acre may be expected on good sites at age 40 in well-stocked stands. This yield equals the 1-cord-to-the-acre growth concept which is the forester's rule of thumb in gauging good production.

MANAGEMENT DYNAMICS AND TECHNIQUES

Many people do not realize that Choctawhatchee sand pine has some very fine qualities. Not only does it have the previously mentioned advantages, but it can also be managed to produce a variety of commercial products--provided that this is the objective.

To emphasize this ability, let me point out some examples that nature has produced. Throughout Eglin, more than 100 superior sand pines have been identified for tree improvement purposes. There are many more which have not been selected, but they are equally as spectacular. One such tree is over 20 inches in diameter, 80 feet tall, and limbless for at least 2½ logs.

From a management concept, it is important to reproduce this quality in trees, not only in individual members, but also in stands of trees over a wide area. I am speaking of developing this quality in natural stands--stands that we now have to work with--rather than in cultured plantations. On

Eglin, there are now some stands which have this characteristic of fast growth, good comparable height, and potential quality. However, there are relatively few. I suspect that some of our past management procedures, such as fire and grazing practices, have not helped the situation.

We are now at the point where we can explore some management dynamics as well as management techniques for developing cultural treatments for natural stands of Choctawhatchee sand pine. The whole idea is to give the forest manager an alternative to his present concept of managing his stands on short rotations with clearcutting and planting. The actual choice represents a compromise between economic, technical, and silvicultural factors. Ultimately, the forest manager may have to recognize that even-aged crops of trees cannot be grown continuously on short rotations without taking into account the biotic factors and the problem of maintenance of soil fertility (as affected by intensive site preparations and so forth).

The discussion of management dynamics is founded on two basic premises. The first concerns the goal of growing the highest-valued product, or products, that the site will produce in the shortest period of time. The second concerns the role that techniques play in developing a major commercial product while also considering the environmental aspects of other uses, such as recreation, wildlife habitat, and aesthetics.

Generally, we think of sand pine as a pulpwood tree growing on a site with low potential for productivity. As such, our management is limited--this is understood. But let us move forward for a moment and consider two distinct prospects. The first regards the growing of sand pine on sites other than poor ones, and the second points to the fact that new markets are opening up in the South. Both of these prospects are quite real.

To explore these prospects, we must change our management directive from the production of pulpwood to that of the alternatives of multiple-products. A shift of emphasis is apparent--from quantity production to quality production. For Choctawhatchee sand pine, quality is defined as that ability to produce a product of greater value than pulpwood, such as short saw logs for studs or short bolts for plywood.

We know that a mature stand of Choctawhatchee sand pine at age 50 can contain as much as 15 thousand boardfeet of merchantable sawtimber, with 10 cords of pulpwood per acre on a good site. Furthermore, we know that sand pine sawtimber is usually knotty and small in size. Yet we know also that, on the average, second-growth southern pine also produces lumber which is lower in quality than is desirable. So what are we looking for in Choctawhatchee sand pine? Maybe we should lower our sights somewhat and look at the market place to see what it will accept in 10 or 20 years, or perhaps 50 years from today.

By the year 2000, the U. S. population will climb to nearly 290 million, if Federal Government projections are correct. This is nearly 80 million more people in this country than we now have. It is the pressure of this added population requiring more timber--in the form of new homes, schools, shopping centers, recreation areas, and the like--that will be the main thrust behind rising timber values in the future.

Not only is the population going to increase by the year 2000, but our timber supply is going to be greatly affected. For one thing, the quality of products that come from the woods is going to be less than what is now being produced.

Until recent years, the local lumber industry has been operating its plants on a supply of timber from the major southern pines. A steady market has been provided with these species, and the result has been a decline in the average tree size. It is in this climate where small-diameter trees are acceptable that an avenue will open for Choctawhatchee sand pine to enter the market. I am convinced that in the near future sand pine will successfully blend with other pines (much of which are already grown in short-rotation, second-growth plantations) in the small-diameter market and possibly in other markets where stud mills and plywood plants compete with the pulpwood companies for the smaller pine trees.

To illustrate how the economics of the small-diameter market might work, let me use part of a table that Jiles (1) developed for natural stands of shortleaf and Virginia pines and for planted stands of loblolly pines in east Tennessee:

D.b.h.	Pulpwood stumpage price per standard cord (dollars)				
(inches)	$1	$3	$5	$7	$9
	Equivalent sawtimber stumpage price per Mbf (dollars)*				
7	4.08	12.24	20.40	28.56	36.72
9	3.28	9.84	16.40	22.96	29.52
11	2.82	8.46	14.10	19.74	25.38
13	2.45	7.35	12.25	17.15	22.05

*Based on International ¼ Inch Log Rule.

The table shows price equivalents for small-diameter trees when used for pulpwood or sawtimber. The price equivalents are based on the number of standard cords required for each diameter class to produce 1,000 boardfeet by the International ¼ Inch Log Rule. For example, the column for

$1 pulpwood stumpage shows that, for the 9-inch diameter class, 3.28 cords is equivalent to 1,000 boardfeet. It also shows that the $1 pulpwood stumpage price is equivalent to $3.28 for sawtimber and that $9 in pulpwood stumpage is equivalent to $29.52 for sawtimber.

The table gives a good dollar-value comparison for small-diameter products. It appears from the table that pulpwood might be competitively pushed if sawtimber stumpage continues to rise as it is now rising in our "seller's market."

Of course, all of this is speculative. But it represents a potential, and it is on this potential that we are gauging our present and future management of natural stands of Choctawhatchee sand pine.

Let me show you what we are thinking about for the future in regard to the 100,000 acres of sand pine that we have at Eglin.

At present, our rotation age for sand pine is 40 years. This is the age at which we believe we can best accomplish our management objectives. We also believe that manipulations of quality are within the scope of the forest manager and that we will develop the intensive cultural practices needed to obtain our multiple-use goals.

Even-aged management will be practiced, with intermediate cuts at 10-year intervals for internal maintenance when needed and harvest cutting at the rotation age. This technique will be applied to good sites first, then to medium sites, and possibly to poor sites if it is economically justified.

Thinning is a cultural tool that we plan to use in its traditional role as a growth regulator and developer of products. It will be applied in the life of a stand on good and medium sites as an improvement operation. Normally, a stocking level of 70 to 90 square feet of basal area per acre will be maintained. The cutting operation will be a conservative one and will remove 5 to 10 cords in the first thinning. The aim is to leave those trees which are vigorous and dominant and which have the best chance for quality growth.

Regeneration is not a problem with Choctawhatchee sand pine. Trees are relatively fruitful at an early age, and usually they have a good cone crop at 4- to 6-year intervals and light crops in intervening years. Cones reach mature size by late summer, and seed dispersal takes place in late October.

At the rotation's end, natural stands of sand pine can be regenerated successfully by either the clearcut or shelterwood method. Both techniques are used at Eglin, but we prefer the shelterwood system.

Our future logging units will be about 50 acres in size at harvest time. The final cut under the shelterwood system will be made as soon as regeneration is adequate. There are some risks with this system, such as an influx of Ips beetles after a cutting, Fomes annosus root rot, and damage to young seedlings. However, it must be remembered that, over large areas in any type of regeneration, complete stocking seldom occurs. As a rule, a young, understocked stand becomes relatively more fully stocked with age. On the other hand, an abnormally dense stand is likely to decline in stocking as it grows older.

One other aspect of management that is available to us as a cultural tool is prescribed burning. We have successfully applied this technique for a number of years in our sand pine areas, but it has been for purposes other than forest management. Sand pine stands are burned in the same manner in which we burn the other pine species. However, there are some minor differences in the results. For one thing, not much fuel accumulates under sand pines; consequently, the fire is not as hot and the scorch line usually is not as apparent.

Over the past 10 years, we have repeatedly burned several young stands of sand pine under "normal" burning conditions. Usually, there have been winter burns which were applied several days after a rain. The result of our burning of sand pine is almost the same as it is with the burning of longleaf and slash pines: it is an effective tool in pruning the lower limbs, and it provides a cleaner ground area for cultural operations.

CONCLUSIONS

What are some of the conclusions to be drawn from this discussion on managing natural stands of Choctawhatchee sand pine? Perhaps one of the most significant is that Choctawhatchee sand pine has several natural characteristics that will allow us to manage it for small-diameter timber products other than pulpwood. As to the market value, I believe our future trees will have a considerably greater earning capacity than the average tree managed to date.

Intensive management of sand pine is just beginning, and markets are developing around this new emphasis on the species. Because of these two bright prospects, I am convinced that sand pine will benefit from the favorable opportunities that the future will present.

Another conclusion that can be drawn is that we should "make the most of what we have." Even at this moment, we possess the necessary tools that will successfully develop natural stands of Choctawhatchee sand pine: our "standard forestry practices." All that we need to do is patiently apply them to this minor species that we have underrated and bypassed for so many years. If this application is made, then Choctawhatchee sand pine will find its place among the other southern pines in meeting the anticipated demands of the future.

LITERATURE CITED

1. Jiles, Robert A., Jr. 1957. Pine stumpage sales for pulpwood and sawlogs in east Tennessee. Tenn. Val. Auth. Tech. Note 30, 20 pp.

MANAGEMENT OF NATURAL STANDS OF OCALA SAND PINE

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Abstract.--After World War II, tremendous acreages of Ocala sand pine reverted to scrub vegetation as a result of the exclusion of fire, natural deterioration of old stands, clearcutting, and the lack of natural and artificial regeneration. Recent research plus on-the-ground practices of the Forest Service show that direct seeding on adequately prepared sites is the best method of reconverting scrub vegetation or cutover areas to Ocala sand pine. Planting has not proved satisfactory. The Seminole Seeder, developed on the Ocala National Forest, allows direct seeding at the time of site preparation and also covers the seeds with soil, thereby improving chances of germination. Once established, little management other than fire protection is practiced.

Ocala sand pine (*Pinus clausa* var. *clausa* Ward), also known as "scrub pine" or "spruce pine," is limited in range to peninsular Florida. Prior to World War II, there was little commercial interest in sand pine forests (or the "Big Scrub," as it was known to the early settlers in central

Florida). It was only after the war that the first extensive cutting of Ocala sand pine for pulpwood took place. Because of the difficulties of regeneration, many cutover, fire-killed, or age-deteriorated stands were left to revert to scrub oaks and other species.

This paper presents information on establishing, growing, and managing the Ocala variety of sand pine under the standard practices of timber management used by the USDA Forest Service on the Ocala National Forest. It is a collection of published knowledge on the subject supplemented by current research and practices used in managing Ocala sand pine.

DISTRIBUTION AND ASSOCIATION

The range of Ocala sand pine is confined to about 32 counties in central Florida. The heaviest concentration is on the Ocala National Forest (more than 200,000 acres) in Lake, Marion, and Putnam Counties. It is also found in a narrow strip along the east coast from St. John's County south into Palm Beach and Broward Counties. On the west coast of the peninsula, it is limited to Hernando and Lee Counties.

Ocala sand pine is also found in longleaf-scrub oak forest types and is rarely associated with other forest types. Associated or understory plants include sand live oak (Quercus virginiana var. maritima (Michx.) Sarg.), myrtle oak (Quercus myrtifolia Willd.), turkey oak (Quercus laevis Walt.), live oak (Quercus virginiana Mill.), sandheath (Ceratiola ericoides Michx.), saw-palmetto (Serenoa repens (Bartr.) Small), and etonia palmetto (Sabal etonia Swingle).

REQUIREMENTS FOR OCALA SAND PINE

Ocala sand pine grows in an area of rolling sandhills varying in elevation from less than 40 feet to about 200 feet above sea level. Numerous lakes and sinkholes are found throughout its range. Astatula and Paola are the major soils supporting Ocala sand pine on the Ocala National Forest (1). These are dry, infertile, acidic soils derived from deep deposits of marine sand and clay. Ocala sand pine sites change rapidly in central Florida because of changes in soil types or moisture conditions. In many instances, roads along type lines separate sand pine from other species.

NATURAL REGENERATION

Factors directly affecting natural regeneration of Ocala sand pine after seedfall include time of year, temperature of the soil surface, soil moisture, and predator populations. Records show that the period between

October and January is most conducive to natural establishment of seedlings (3). Temperature of the soil surface at other times of the year can prohibit satisfactory establishment of Ocala sand pine, especially when it exceeds 130° F. Soil moisture must be in adequate supply for both germination of seeds and establishment of seedlings.

The principal predators of seeds of Ocala sand pine include many species of birds, the Florida deer mouse (Peromyscus floridanus), the oldfield mouse (Peromyscus polinotus), and the Florida harvester ant (Pogonomyrmex badius Latreille). Any of these factors can contribute to erratic germination of seeds and poor survival of seedlings.

Before the days of cutting and fire protection, unmanaged forests of Ocala sand pine regenerated naturally as a result of fire. Wildfires moved through large acreages, burning and destroying the forest. But it was only through this means that the serotinous cones of Ocala sand pine would open and release their seed on a fresh seedbed. Cooper et al. (3) reported collecting samples comprised of more than 1,000,000 seed per acre in dense stands and about 420,000 seed per acre in open stands 3 weeks after a fire. Forty percent of these seed were viable, and early examinations showed high seedling counts per acre. Dense, even-aged forests resulted when weather and site conditions allowed germination and establishment of seedlings.

Some natural regeneration also occurs after clearcutting operations. Forest Service personnel on the Lake George Ranger District of the Ocala National Forest have reported satisfactory regeneration after cutting a dense stand. This regeneration probably occurred when sunlight opened the cones on downed tops and the seeds reached mineral soil. Such cases are the exception rather than the rule. Adequate distribution of seeds from tops is not predictable. The result is often poorly regenerated stands. A large portion of the seeds are also consumed by predators, who have unrestricted access to them as they are released.

Harrington and Riebold (4) reported that the shelterwood method holds promise as a means of natural regeneration on the Ocala National Forest. Their study indicated that seedling counts were significantly higher with this method than with clearcutting but were still less than acceptable minimum stocking (280 seedlings per acre on National Forest lands). The shelterwood method permits sunlight to open cones on logging slash, while the remaining trees provide sufficient shade to protect newly germinated seedlings.

ARTIFICIAL REGENERATION

During the years following World War II, about 30,000 acres of land on the Ocala National Forest reverted to scrub vegetation as a result of extensive cutting, a high incidence of wildfires, deterioration of old stands, and a lack of natural regeneration. This area needed conversion to sand pine by artificial means.

In the sand pine types of central Florida, some form of site preparation or scarification is a prerequisite to artificial regeneration. Site preparation, whether by disking, chopping with brush cutters, or prescribed fire, helps to eliminate or reduce the brush or logging slash and exposes mineral soil needed for a satisfactory seedbed or planting area. Disking is an effective means of site preparation when brush or logging debris does not prohibit the blades from reaching and effectively disturbing the soil. Prescribed fire has also been used successfully to reduce or eliminate surface cover and prepare seedbeds. Predicting suitable conditions for burning is not always possible, and many backfires change into hot head fires with unpredicted and sudden changes in windspeed and direction. Prescribed burning involves a risk not present with other methods of site preparation.

In the Ocala sand pine forest, chopping with brush cutters is probably the best and most widely used means of obtaining both good brush reduction and exposed mineral soil. All brush and logging debris, as well as unwanted residual vegetation up to 4 inches in diameter, can be incorporated into the soil with these machines. The large-diameter material is not easily chopped or broken, but single or scattered individuals can be pushed down with the heavier tractors and later burned. Depending upon the amount and size of the material, a second or double chop may be necessary in order to obtain adequate site preparation. If sufficient cured vegetation remains after chopping, the sites can be burned to further eliminate surface litter. It is presently the policy of the Forest Service on the Ocala National Forest to specify Marden® brush cutters (11-ton, B-7 model) because this cutter gives better cutting and rough reduction plus adequate soil disturbance.

Most early attempts at planting Ocala sand pine resulted in failure. Sand pine seedlings are apparently extremely sensitive to shock from transplanting. Root disturbance also has resulted in the death of otherwise healthy, mature trees (3).

Direct seeding at a rate of 0.5 to 1 pound of seed per acre after some form of site preparation has been the most practical and successful means of regenerating Ocala sand pine to date. Direct seeding usually is done during the 4-month period from October to January in order to ensure satisfactory establishment of seedlings.

On the Ocala National Forest, many methods of direct seeding sand pine have been used--with varying degrees of success. Tractor seeding, aerial seeding, and some hand seeding have been done. Up to the present time, most regeneration has been obtained by chopping, burning, and aerial seeding.

Many problems became important and had to be solved with the available methods of artificial regeneration. Among the problems encountered were increasing pressure from the public sector regarding cutting and regeneration on the Ocala National Forest, the apparent high number of failures in aerial seeding, the elimination of endrin-treated seed on National Forest lands, concern for wildfires and smoke pollution by neighboring landowners during site-preparation burns and increasing costs as a result of recent changes in the size and shape of regeneration areas.

To solve these problems and to ease some of the public's concern, a seeder was needed that could be used for direct seeding of Ocala sand pine at the time of mechanical site preparation. Such a seeder would eliminate the separate operations of burning and aerial seeding and would also incorporate the seeds into mineral soil. Hodges and Scheer (5) found that sand pine seeds covered with a thin layer of soil (0.25 to 0.75 inch) germinated better than those lying on the surface. Because endrin-treated seeds could no longer be used on National Forest lands, a soil cover to reduce predator losses became even more important.

The Seminole Seeder (fig. 1), developed on the Ocala National Forest, has proven satisfactory and makes it possible to combine site preparation, seeding, and covering of seeds into a single operation. This seeder is a durable, self-contained, gas-powered machine that can be mounted on almost any type of ground carrier (crawler or wheeled tractor). With the Seminole Seeder, it is possible to reduce the regeneration of Ocala sand pine from a 6- to 8-month operation to a single operation combining site preparation and seeding. In heavy brush, seeding is combined with the required second chop.

Four areas seeded with the Seminole Seeder at the rate of 1 pound of seed per acre gave satisfactory results on three of four areas (between 480 and 670 seedlings per acre with 280 per acre necessary for success). Areas seeded from the air under similar conditions were below the minimum requirements for stocking. In future years, this seeder will play an important part in artificial regeneration of sand pine on the Ocala National Forest.

RECOMMENDATIONS FOR ARTIFICIAL REGENERATION

Although satisfactory artificial regeneration of Ocala sand pine is possible, it presents unique and complex problems. Following are some recommendations to improve chances of a successful first-year seed catch:

1. Do not skimp on site preparation. Apply a second chop when it is required. Areas of heavy brush, even when chopped once and burned, can still have a thick layer of surface or organic litter, quick-sprouting scrub species, and unburned spots that prevent seeds from reaching mineral soil and becoming established.

2. Do not mechanically prepare and burn too far in advance of seeding if seeding at the time of site preparation is not anticipated. Fresh site preparation provides less chance for a sand crust to form or for excessive sprouting of scrub species. The crust and hardwood sprouts make it difficult for germinating seeds to become established.

3. Seed Ocala sand pine during October and November. Seeding in the fall allows extra time for seedling establishment and cuts losses during the following spring and summer months.

4. Direct seeding should be done at the rate of 0.5 to 1 pound of seed per acre. The 1-pound rate is particularly important when effective controls of predators are not available or cannot be used or when no covering of seeds is planned. If treated seeds can be safely used to cut losses from predators or if covering of seeds is planned, the 0.5-pound rate should be sufficient.

5. Whenever possible, cover the seeds after seeding or, better yet, seed and cover in a single operation. A farm tractor equipped with a drag will cover the seeds and thereby reduce seed losses to predators while improving chances of a successful catch.

6. Seek means of combining site preparation, seeding, and covering of seeds in one operation. Seeding in front of a Marden® brush cutter has proven successful on the Seminole Ranger District.

PROTECTION

Once established, Ocala sand pine is capable of surviving high temperatures, periods of drought, insects, and disease. Cooper (2) reports that gall rust (Cronartium quercuum (Berk.) Miy.) is common but not serious. However, he reports that red heart (Fomes pini (Thore) Lloyd) is frequently present in older trees. The black turpentine beetle (Dendroctonus terebrans Oliv.), southern pine beetle (Dendroctonus frontalis Zimm.), and Ips engraver beetles (Ips spp.) kill sand pine, particularly those injured or weakened by fire.

Fire is the most serious enemy of Ocala sand pine, even though this species probably owes its very existence to fire. Ocala sand pines are easily killed by fire. The settlers' cry of "Fire in the Scrub" usually meant thousands of burned acres. Wildfires in stands of Ocala sand pine are difficult to control. Crown fires can race uncontrolled for miles, killing trees and cone-stored seeds alike.

GROWTH AND YIELD

Cooper (2) reports that root growth and development is rapid (up to 2 inches in 10 days) if the radicles can survive extreme temperatures and soil moistures. Later growth usually occurs in two spurts each year. Height growth varies considerably, but it has been reported to be as much as 24 inches annually. A 3-year-old seedling will average about 3 feet in height. Ocala sand pine exhibits remarkable tolerance to competition and shade immediately after establishment. Little dominance is expressed in it usual growth patterns (6, pp. 447-450).

On the best sites (index 70), mature sand pines should average 16 t 18 inches in diameter and 70 feet in height (6, pp. 447-450). On average sites (index 60), average diameter at maturity should be 12 to 13 inches and height should be 60 feet. On the poorer sites (index 50), mature trees shoul average 8 to 10 inches in diameter and 50 feet in height. Pulpwood yields vary from 8 to 20 cords per acre, depending on site index and age when cut. Quality yields tend to fall off with age because of red heart.

MANAGEMENT AND MARKETING

From sapling stage to maturity, little actual management other tha fire protection is practiced on Ocala sand pine. At present, Forest Service practices do not include precommercial thinnings, intermediate cuttings, or fertilization. In time, research may tell whether these or other practices are necessary and economical in the sand pine types.

Because of its poor form and appearance, Ocala sand pine is used almost totally for pulpwood. From age 4 to 10, most of these trees have an excellent conical shape, making them good prospects for Christmas tree in and around central Florida. At present, a relatively small number are sold each year by the Forest Service for this purpose. Although the production of Christmas trees is not a part of our management practice, it should not be overlooked by either the National Forest or private land managers.

The actual input of Ocala sand pine into Florida's wood-using industry is small (less than 5 percent of total consumption), but it is especial important in times of prolonged rains (7). Most of the sales made on the Ocala National Forest are area-estimate sales in which pulpwood volumes are determined on an acreage basis. All merchantable material is then offered on a lump-sum basis to prospective buyers. Under normal sale conditions, no marking is practiced. Prices for pulpwood of Ocala sand pine currently run between $8 and $10 per cord. Most sales, especially those of sizable volume, are readily purchased.

LITERATURE CITED

1. Aydelott, D. Gray, and Bullock, H. C. 1972. Soils of the Ocala National Forest. USDA For. Serv., South. Reg., Atlanta, Ga., 39 pp.
2. Cooper, Robert W. 1957. Silvical characteristics of sand pine. USDA For. Serv. Southeast. For. Exp. Stn. Pap. 82, 8 pp.
3. Schopmeyer, Clifford S., and McGregor, William H. Davis. 1959. Sand pine regeneration on the Ocala National Forest. U. S. Dep. Agric. Prod. Res. Rep. 30, 37 pp.
4. Harrington, T. A., and Riebold, R. J. 1967. The shelterwood method for regenerating sand pine. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Note SE-67, 2 pp.
5. Hodges, J. D., and Scheer, R. L. 1962. Soil cover aids germination of pine seed on sandy sites. USDA For. Serv. Tree Plant. Notes 54: 1-3.
6. Fowells, H. A. 1965. Silvics of forest trees of the United States. USDA For. Serv. Agric. Handb. 271, 762 pp.
7. USDA Forest Service. 1972. Plan for managing the Ocala National Forest. Natl. For. Fla., Tallahassee, 53 pp.

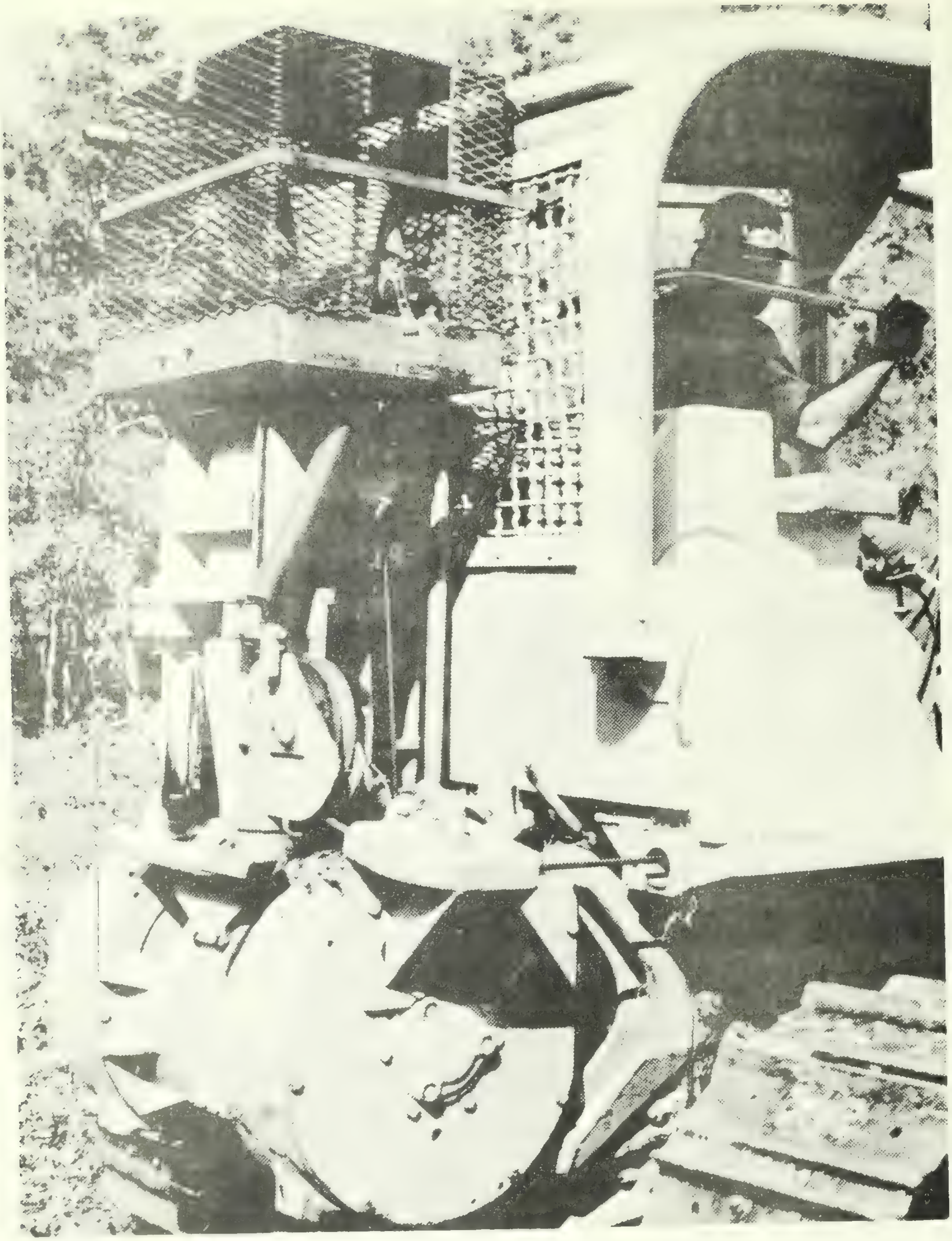

Figure 1.--The Seminole Seeder.

MANAGEMENT OF SAND PINE PLANTATIONS

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Abstract.--Information on site preparation, planting density, thinning, length of rotation, estimated plantation yields, and regeneration is provided for land managers interested in converting sandhill land from scrub hardwoods to sand pine.

INTRODUCTION

The four questions most frequently asked by land managers interested in converting sandhill land from scrub hardwoods to sand pine (*Pinus clausa* (Chapm.) Vasey) are:

A. How should the site be prepared?
B. How many pines should be planted per acre?
C. Should the plantation be thinned? If so, when and how often?
D. How much volume will a sand pine plantation produce in one rotation?

The answers to these and related questions form the basis of this paper. These answers are founded on the limited amount of data presently available from sand pine plantations, on best estimates of projected performance, and on the author's 10 years of experience in working with sand pine.

The productive potential of the site and objectives of the land manager are of paramount importance in providing appropriate answers. Sandhill soils are droughty and infertile; the growing season is relatively long, hot, and wet. Under these circumstances, there is little that can be done to alter the site's productive potential economically. Site potential is comparatively low and limits the number of practical alternatives to pulpwood production on a short- to medium-length rotation.

SITE PREPARATION

Previous papers in this symposium have shown that sand pines will survive and grow well when planted among scrub hardwoods but that they grow faster when released from competition or when they are planted on a prepared site. However, the growth stimulus provided by complete and intensive site preparation may not warrant the added expense, especially in the face of increasing costs for machinery, supplies, labor, and money. Integrated management for pulpwood and Christmas trees, as suggested by remarks in a previous paper, may offer an opportunity to offset rising costs. It may also pose additional problems of management and marketing. Therefore, until its practicability has been tested, management for both pulpwood and Christmas trees cannot be recommended.

The ability of sand pine to survive and grow well with only minimal site preparation is important economically, but the species is also useful in preserving the natural appearance and wildlife potential of woodlands. The previous paper on site preparation showed that sand pines are well-suited for planting on narrow strips prepared in roughs composed of scrub hardwoods and wiregrass. By varying the width of undisturbed rough and by causing prepared strips to meander so as to avoid straight rows, conversion to sand pine can be esthetically acceptable, economically feasible, and can aid in improving the wildlife habitat. The width of prepared strips and undisturbed rough may be varied to meet specific objectives, but, for optimum juvenile growth, prepared strips should be at least 2 to 4 feet wide. Alternatives include wide, prepared strips planted with several rows of seedlings separated by an undisturbed rough wide enough to provide food and access for game and also to avoid the appearance of a monoculture.

DENSITY AND SPACING OF TREES

The carrying capacity of the site limits the maximum number of sand pine seedlings that should be planted. With normal rainfall, a prepared acre in the sandhills might be expected to carry about 1,550 trees through age 8; 800 through age 15; 600 through age 20; and 350 to 450 through age 35 without stagnating. This means that if first-year survival of 85 percent and subsequent mortality of about 5 percent can be anticipated, a planting of 500 to 550 seedlings of Choctawhatchee sand pine (_P. clausa_ var. _immuginata_

Ward) per acre will produce 400 to 450 trees at plantation age 30. If a thinning is planned, about 725 to 775 seedlings per acre can be planted. By age 20 the plantation should contain 600 to 650 trees. Thinning to remove every third row or every third row plus suppressed and diseased trees in the remaining rows will leave about 350 to 425 trees for a later harvest. Similar results can be obtained with Ocala sand pine (P. clausa var. clausa Ward), but more seedlings will have to be planted to compensate for the higher rate of mortality typical with this variety.

The spatial arrangement of seedlings on the acre depends on the number to be planted, degree or method of site preparation, and method of harvest. Row-thinning by machine, for example, requires rows spaced at least 8 or 10 feet apart to avoid seriously damaging residual trees.

On unprepared or completely prepared land, any spacing between trees and rows that results in uniform distribution and provides for the possibility of machine-thinning may be used. If no thinning is planned, 500 to 550 seedlings can be planted per acre; each will have 78 to 88 square feet of growing space. At present there does not appear to be any special advantage associated with square spacing; consequently, spacings of 8 by 10 feet, 8 by 11 feet, or 9 by 9 feet can be used to equal advantage. Extreme rectangularity, e.g., 4 by 22 feet, should be avoided, however, because trees spaced closely within rows become crowded and seldom fully occupy the wide expanse between rows. If a single thinning is planned, planting density can be increased to 725 to 775 seedlings per acre. Spacings of 6 by 10 feet or 7 by 8 feet, with rows no closer than 8 feet, should result in a stand of 600 to 650 trees spaced to accommodate row-thinning with machines at age 20.

A somewhat different situation exists when prepared strips are planted. Individual strips may be wide enough to accommodate several rows of seedlings or so narrow that only a single row can be planted. In either instance, rows--and seedlings within rows--should be spaced within the prepared strip so as to most fully utilize potential growing space in both the prepared land and the adjacent, unprepared rough.

THINNING

Several factors affect the decision as to whether sufficient trees should be planted for a planned thinning. If pulpwood is the objective, more usable cellulose can usually be produced by allowing for anticipated mortality and planting as many trees as the site will effectively support throughout a rotation. In the sandhills, this may mean planting 500 to 550 trees per acre and carrying 350 to 400 for 30 years or more. But measurements of existing, relatively high-density plantations suggest that sandhill sites will support as many as 600 sand pines per acre through age 20 without excessive crowding. A row thinning to remove one-third or more trees per acre might be made at this time, leaving 350 to 400 for a harvest cut. At this level of stocking, it appears unlikely that more than one thinning would be feasible.

The question remains as to whether total production from the 600-tree stand thinned at age 20 to 400 trees and harvested at about age 30 will sufficiently exceed that of an unthinned, 400-tree stand harvested at the same age so that the added expense for seedlings, planting, marking, and thinning plus accrued interest on the outlay will be justified. In the comparison that follows, data from figures 1 and 2 were used to predict tree size; the equation for merchantable height was developed from a 28-year-old plantation of Choctawhatchee sand pine as reported by Burns and Brendemuehl (2): Merchantable height = $-47.26138 + 16.85121 \text{ d.b.h.} - 0.80507 \text{ d.b.h.}^2$; and cubic volume to a 4-inch top (outside bark) was computed from table 49 of the "Forestry Handbook" (3) on the basis of the following equation. Volume in cubic feet = $0.2618\ L\ \left(\frac{D^2 + d^2 + dD}{144}\right)$, where L = length, D = diameter (outside bark) at large end, and d = diameter (outside bark) at merchantable top.

Site differences do exist even in the seemingly uniform sandhills. Because so few sand pine plantations are of sufficient size to establish indices of site quality, however, differences in site quality cannot be accounted for at this time. For this reason, and because at age 20 sand pines are at the threshold of merchantability, too much credence should not be placed in the accuracy of estimated yields in the following discussion. Volume estimates are presented primarily for comparative purposes.

At age 20 the 600-tree stand will average 5.6 inches d.b.h. and 43 feet in height. These trees will contain 21.5 feet of merchantable length to a 4-inch top and 2.66 cubic feet of wood. Probably the cheapest method of thinning a plantation is by rows, because rows need no marking. Theoretically, this method removes a representative number of trees of all sizes; therefore, both the 200 trees removed and the 400 remaining will contain an average of 2.66 cubic feet of wood. The thinning will yield about 535 cubic feet of wood per acre, and the 400 residual trees will contain about 1,065 cubic feet. In contrast, the 400 trees in the unthinned stand will average 5.8 inches d.b.h., 23.7 feet of merchantable length, and contain 3.07 cubic feet of wood (about 1,230 cubic feet per acre). Although it seems unlikely that residual trees in the thinned stand will make an immediate response to release, it is assumed that the 400 trees in the unthinned and the residual stands grow at the same rate for the next 10 years.

When harvested at age 30, the 400 residual trees will average 6.7 inches d.b.h., 28.3 feet of merchantable length, and 4.43 cubic feet of wood. The stand will have produced 535 cubic feet from the thinning and 1,770 cubic feet at harvest, for a total of 2,305 cubic feet. The 400 unthinned trees will average 6.9 inches d.b.h., 30.5 feet of merchantable length, and 4.97 cubic feet of wood. The stand will have produced 1,990 cubic feet of wood or about 315 cubic feet less volume than the thinned stand. The land manager must decide whether differences in returns justify the additional expense associated with the thinned stand.

Unforeseen events may dictate that a harvest before age 30 is necessary. In this event, the manager may anticipate a return of about 1,600 cubic feet from the 600-tree stand and about 1,230 cubic feet from the 400-tree stand at age 20. The difference in yields from the 400- and 600-tree stands remains essentially the same, i.e., 315 cubic feet at age 30 and 370 cubic feet at age 20.

Bennett (1) has discussed other factors to be weighed before deciding if thinning is practical in slash pine plantations. His remarks seem equally pertinent for the production of sand pine pulpwood on low-quality sites over a 25- to 40-year rotation. He concludes (1, p. 14) that, "...in plantation management oriented around products, product objective should determine initial spacing; and, in rotations of short to medium length, thinning should play a secondary role, mostly as a sanitation and salvage measure, and not be viewed as essentially a growth regulator or product developer."

Length of Rotation

There is no apparent advantage to borrowing money at 6 percent and investing it at 6 percent, or less. The same principle should hold true for managing a pine plantation. When a plantation no longer produces wood at a rate sufficient to show a profit above that needed to offset establishment costs and the interest charged against that investment, it should be harvested. Economically, this is the rotation age.

From the standpoint of volume growth, length of pulpwood rotation should coincide with, or slightly precede, the age at which curves depicting current annual increment (CAI) and mean annual increment (MAI) intersect. Our sand pine plantations are too young to yield these data. However, with slash pine (1), loblolly pine (4), and presumably other southern pines including sand pine, comparable patterns of CAI and MAI exist. The curves intersect later for poor sites than for high-quality sites and, for any given site quality, later for densely stocked stands than for lightly stocked stands. The quality of sandhill sites is poor. Available data indicate that the optimum stocking level on most sandhill sites is about 400 sand pine per acre. If so, then the coincidence of CAI and MAI curves for sand pine will occur at about plantation age 35. However, because the two curves presumably intersect at a slight angle, harvesting could conceivably be done as early as plantation age 30 with no meaningful sacrifice in volume. From both an economic and a technical standpoint, it presently appears that a rotation of about 30 to 35 years will be most practical for the management of sand pine plantations.

YIELDS AT PLANTATION AGE

Existing plantations are too young and too limited in number and diversity of site to permit accurate estimates of merchantable volume for sand pine. Only one plantation of Choctawhatchee sand pine is of sufficient size to provide useful information. On an unprepared site, 354 trees per acre produced approximately 3, 125 cubic feet of merchantable pulpwood at age 35 (2). Data extrapolated from this plantation and mediated somewhat by measurements from younger plantations on prepared sites are presented in table 1. They represent a reconstruction and projection of average tree size and merchantable volume at several ages and densities of stocking.

REGENERATION

Some natural regeneration will undoubtedly occur. Serotinous cones of Ocala sand pine open when heat reflected from the sand is trapped in the logging slash. An understory of Choctawhatchee sand pine will probably exist before harvest in light- and medium-stocked stands. If the harvest is timed to take advantage of the current seed crop of Choctawhatchee sand pine, additional seedlings will result. If, within 1 year of harvest, natural seedlings are distributed over the area in manageable numbers, nothing further need be done. Seldom does this occur to the satisfaction of the land manager, however.

In naturally regenerated stands, as in direct-seeded stands, uneven distribution and extremes of stocking are the rule rather than the exception. Too many pine seedlings can be as troublesome as too few. Rarely does interplanting to bolster stocking and rectify patchy distribution or noncommercial thinning to prevent stagnation of an overly stocked stand give satisfactory results.

Planting 1-0 seedlings during the dormant season is currently the most reliable method of insuring desired stocking levels and uniform distribution. Choctawhatchee sand pine is the recommended variety to plant. First-year survival usually averages 10 to 40 percent higher than that of Ocala sand pine, and, with Choctawhatchee sand pine, there is less likelihood of subsequent mortality from mushroom root rot (Clitocybe tabescens (Fr.) Bres.). Early survival of both varieties can be improved by planting dormant seedlings deep in the sand. To do so, nursery stock must be obtained in January or February and planted so that the lowest whorl of green needles is covered with soil. One additional advantage to planting for the second rotation is the future availability of superior seedlings of sand pine. Some seed orchards of sand pine may be in full production in about 10 to 15 years.

Disease, insects, natural pine reproduction, existing and sprouting hardwoods, and slash from the previous harvest may pose problems. The

Table 1. --Estimates of merchantable size and volume per acre at various ages and densities as projected from measurements of a 35-year-old plantation of Choctawhatchee sand pine and supplementary data

Trees per acre (number)	At plantation age--											
	20 years			25 years			30 years			35 years		
	D.b.h.[a]	Height[b]	Vol./acre[c]	D.b.h.[a]	Height[b]	Vol./acre[c]	D.b.h.[a]	Height[b]	Vol./acre[c]	D.b.h.[a]	Height[b]	Vol./acre[c]
	In.	Ft.	Cu. ft.	In.	Ft.	Cu. ft.	In.	Ft.	Cu. ft.	In.	Ft.	Cu. ft.
300	6.2	25.5	1,075	6.8	30.7	1,475	7.3	34.1	1,825	7.8	36.5	2,100
350	6.1	24.9	1,200	6.8	30.2	1,675	7.3	33.6	2,050	7.7	36.1	2,400
400	6.0	24.1	1,325	6.7	29.5	1,850	7.2	33.2	2,300	7.6	35.7	2,675
450	6.0	23.5	1,425	6.6	29.0	2,000	7.1	32.7	2,500	7.6	35.3	2,950
500	5.9	22.7	1,500	--	--	--	--	--	--	--	--	--
550	5.8	22.0	1,575	--	--	--	--	--	--	--	--	--
600	5.7	21.2	1,625	--	--	--	--	--	--	--	--	--

[a] D.b.h. (in.) = $-1.8093 + 6.4956 (\log_{10} \text{age}) - 0.0015$ (No. trees/acre). $R^2 = 0.87$.

[b] Merchantable height (ft.) = $-109.4261 + 38.0947$ (d.b.h.) $- 3.2026$ (d.b.h.^{2}) $+ 0.0922$ (d.b.h.^{3}). $R^2 = 0.70$.

[c] Merchantable volume to a 4-inch top outside bark (rounded to nearest 25 cu. ft.)

$$= 0.2618 \text{ (merchantable height - .05 ft.) } \left(\frac{\text{d.b.h.}^2 + 4^2 + 4 \text{ d.b.h.}}{144}\right) \text{ (No. trees/acre).}$$

probability of infecting the new plantation with root rot caused by Fomes annosus (Fr.) Karst.) can be lessened by treating freshly cut stumps with granular borax. Damage from reproduction weevils can be avoided by waiting one growing season before planting. Problems with natural reproduction, scrub hardwoods, and slash disposal may be remedied with a light- or medium-weight chopper, depending upon local conditions. Prescribed burning cannot be recommended because, in addition to other adverse environmental effects, fire destroys organic matter needed to maintain the productivity of infertile sandhill soils.

SUMMARY

Complete, intensive site preparation appears to be unnecessary for the successful establishment of sand pines in the sandhills. Site preparation in strips may serve as well and, in addition, promises to improve both the wildlife habitat and the esthetics of the area. Low productivity of most sandhills limits stocking to about 600 trees per acre through age 20 and to 350 to 400 trees per acre through age 35.

Choctawhatchee is preferred over Ocala sand pine because of its greater resistance to mushroom root rot and its higher rate of survival. Planting 500 to 550 Choctawhatchee sand pine per acre should provide 350 to 425 trees for harvest at a pulpwood rotation estimated to be between 30 to 35 years. Planting density for sand pine should be aimed at maximum pulpwood production; thinning to achieve this end does not appear practical. Depending upon site quality, an unthinned stand of 400 sand pine might be expected to yield as much as 2,975 cubic feet of merchantable pulpwood at plantation age 35.

Future technology and the availability of superior growing stock of sand pine obviate recommendations other than deep planting and the use of 1-0 planting stock for regenerating harvested plantations for a second rotation.

LITERATURE CITED

1. Bennett, F. A. 1971. The role of thinning and some other problems in management of slash pine plantations. Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-86, 14 pp.

2. Burns, R. M., and Brendemuehl, R. H. 1969. Yield of a Choctawhatchee sand pine plantation at age 28. Southeast. For. Exp. Stn., U.S.D.A. For. Serv. Res. Note SE-103, 4 pp.

3. Forbes, R. D. (ed.). 1955. Forestry handbook. 1143 pp. New York: The Ronald Press Co.

4. Wahlenberg, W. G. 1960. Loblolly pine: its use, ecology, regeneration, protection, growth and management. 603 pp. Duke Univ. Sch. For.

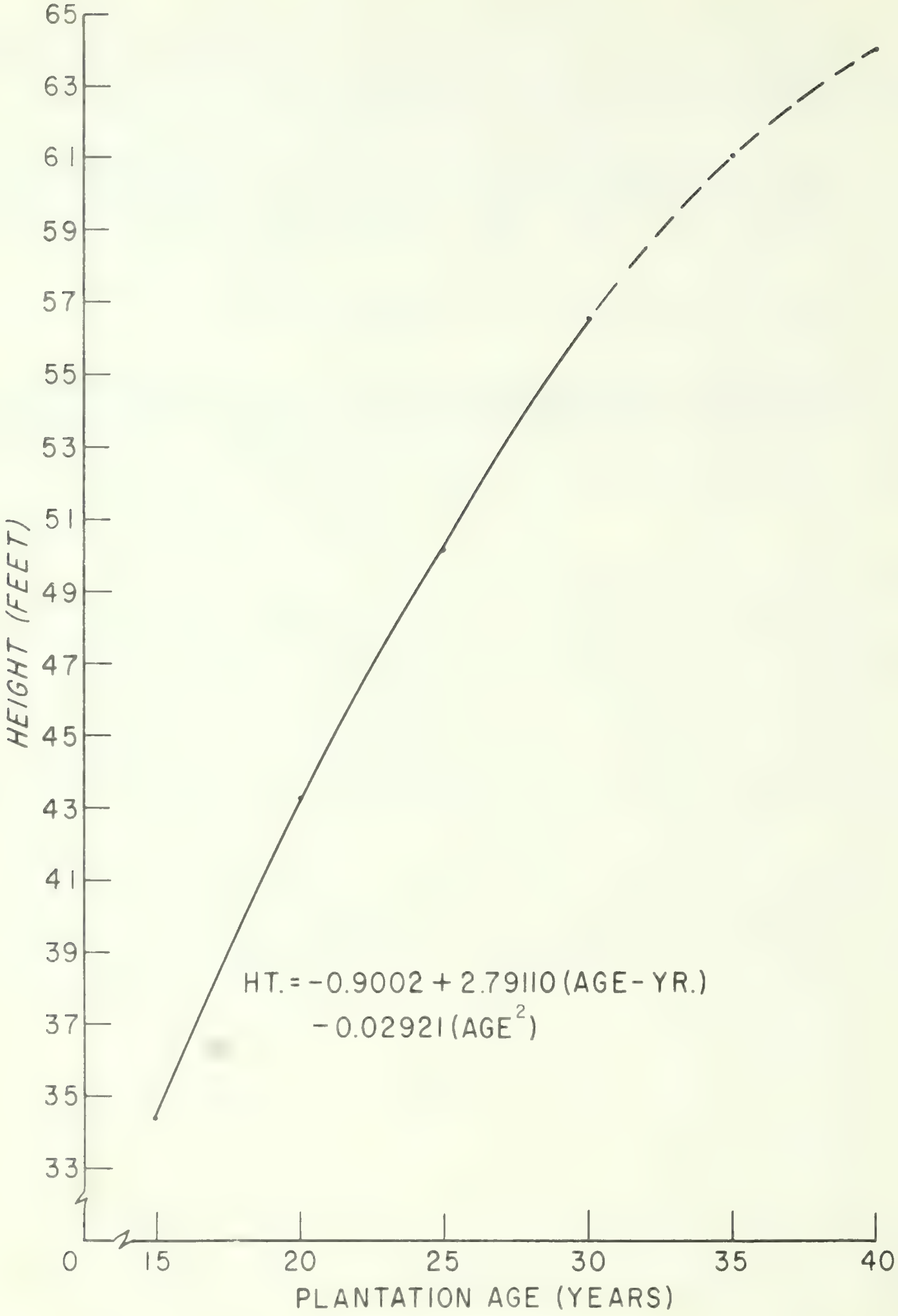

Figure 1. --Average tree height as projected from available data on Choctawhatchee sand pine.

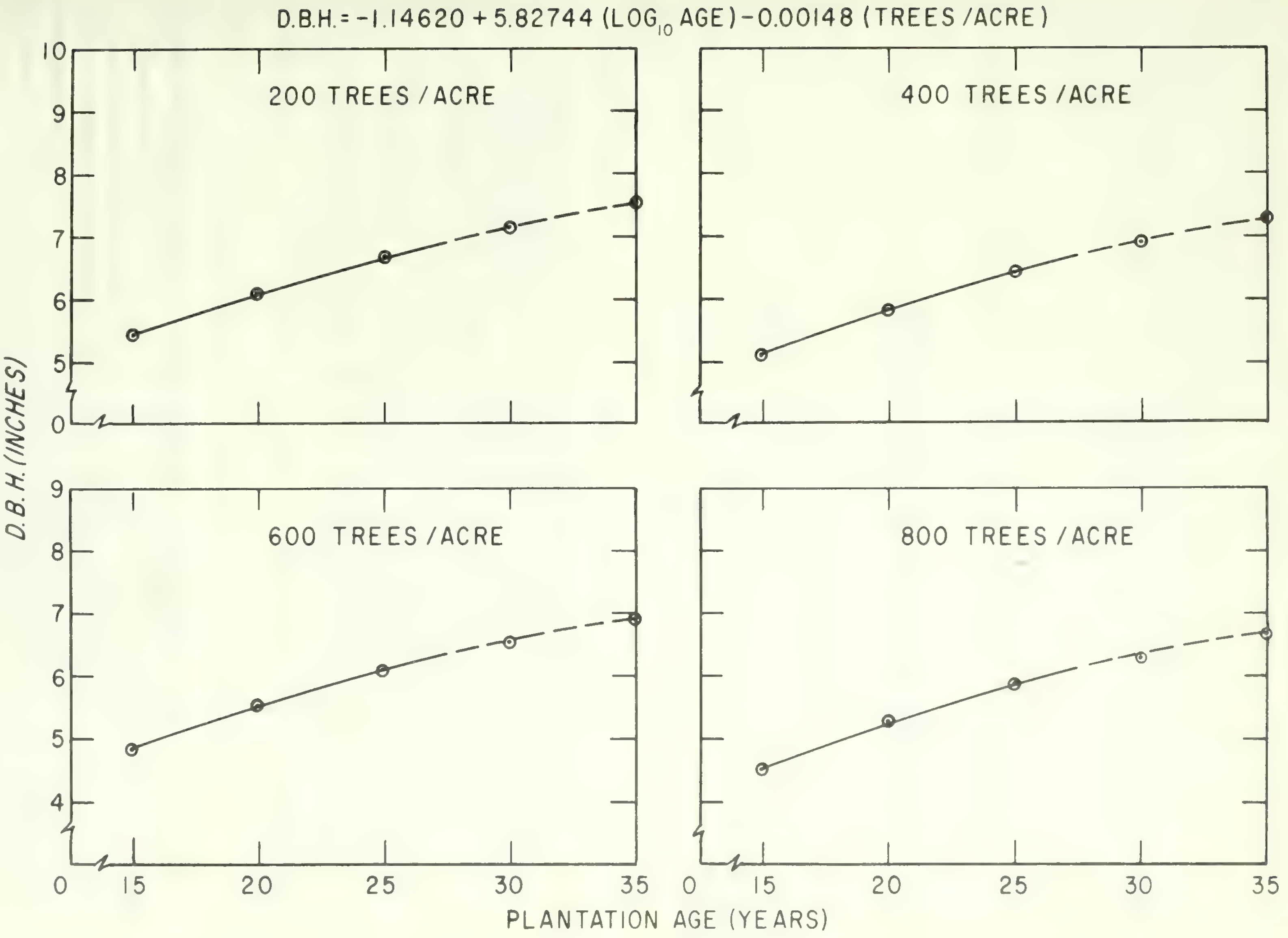

Figure 2. --Average d. b. h. of existing plantations of Choctawhatchee sand pine at various densities.

SOME RESPONSES OF SAND PINE TO FERTILIZATION

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Abstract.--Sand pine seedlings growing on a common sandhill soil, the Lakeland series, have been fertilized with N and P under greenhouse and field conditions. P has proven to be the major plant nutrient that is most deficient for tree growth on this type of soil. A marked growth response to added N fertilizers results after correction of the P deficiency. Foliar nutrient concentrations associated with the maximum growth produced in sand pine seedlings during these investigations are as follows: N = 1.4 percent, P = 0.16 percent, K = 0.6 percent, C = 0.6 percent, and Mg = 0.04 percent.

Sand pine (Pinus clausa var. clausa and var. immuginata Ward) at first glance appears better suited to grow on a medium of sand and water than all the other southern pines. Soils common to its natural habitat are deep, excessively drained sands. These soils are extremely infertile and lack characteristics which favor moisture retention even for short periods of time. Soils which fit this description and support natural stands of sand pine include the Lakeland, Kershaw, Astatula, and Wicksburg series.

An examination of either natural stands or plantations of sand pine also lends support to the idea that the nutrient and moisture requirements of this species are extremely low. Understory vegetation is usually sparse or completely lacking. The sites do not appear to support much in addition to sand pine. Somewhat the same impression is given when one examines the scrub oak and wiregrass cover common to large areas of the sand ridges. Total plant production or total biomass of these scrub oak communities is much smaller than the total volume of plant material produced by a sand pine plantation.

If we compare the nutrient concentrations of sand pine needles with those of other southern pines, we find the former to be substantial (table 1).

Table 1.--Nutrient concentrations in needles of some southern pines

Species	Tree age	Nutrient concentration				Physiographic region
		N	P	K	Ca	
	Yr.	-----	Percent	-----		
Pinus clausa var. clausa Ward	7	1.28	0.10	0.30	0.41	Sandhills
P. clausa var. immuginata Ward	7	1.40	.11	.32	.37	Sandhills
P. elliottii Engelm.	7	.96	.08	.29	.34	Sandhills
P. palustris Mill.	15-20	1.02	.08	.52	.18	Sandhills
P. elliottii Engelm.	10	.96	.09	.30	.21	Coastal Plain (5)[a]
P. taeda L.	7-21	1.02	.10	.43	.29	Piedmont (2)[a]

[a] Numeral refers to literature citation.

In the sandhills, the native habitat of sand pine, the nitrogen (N) concentration of sand pine needles may be 20 to 25 percent greater than that of another sandhill native, longleaf pine (P. palustris Mill.). We find essentially the same relationships when comparing the phosphorus (P) concentrations in the needles of these two sandhill natives.

A comparison of the N and P concentrations in sand pine needles with those in slash pine needles produces much the same answer. Sand pine needles have a higher concentration of both N and P than do those of slash pine growing either in the sandhills or the Coastal Plain. Further examination of table 1 shows the N and P concentrations in loblolly pine needles to be greater than those in either slash or longleaf pine needles but lower than those in sand pine needles. The same relationships do not hold true for potassium (K) and calcium (Ca) concentrations in the needles of the pines listed in table 1, but the values for these elements in sand pine are comparable to those in the other species.

By now it should be readily apparent that sand pine does not thrive on just sand and water. It also requires N, P, K, and other elements essential for plant growth. Because it thrives where other species fail, sand pine must also be extremely efficient at extracting essential growth elements from the soil and at maintaining a desirable internal balance of nutrients and moisture. This capacity gives us the opportunity to modify the nutrient supply of sandhill soils, perhaps to the advantage of this pine species.

SEEDLING RESPONSES TO FERTILIZATION

Several greenhouse studies have been conducted by the Southeastern Station at Marianna to determine the effects of N, P, and K fertilizers on the growth of sand pine seedlings. Both the Ocala (OSP) and Choctawhatchee (CSP) varieties have been included in these studies. This discussion is limited primarily to the work concerned with CSP, but in general the results also apply to OSP seedlings.

The fertilizer treatments applied in these studies included N (as ammonium nitrate) at rates up to 240 pounds of N per acre, P (as monocalcium phosphate) at rates up to 350 pounds of P per acre, and K (as potassium chloride) at rates up to 150 pounds of K per acre. These fertilizer treatments were applied in factorial combinations, and the effects were tested statistically by appropriate analysis of variance procedures.

Soil used for greenhouse studies of this type was collected from the 0- to 10-inch portion of a Lakeland sand profile. The soil was collected from an undisturbed scrub oak stand on a sand ridge site in the Chipola Experimental Forest in Calhoun County, Florida. This soil was analyzed by appropriate laboratory procedures. The results of these analyses are reported in table 2.

Table 2.--Summary of soil analyses of Lakeland sand at 0 to 10 inches

Sand	Silt	Clay	Organic matter	Total N	Ext. P	Ext. K	pH
Percent					P.p.m.		
92.5	2.5	5.0	1.10	0.03	0.37	14.0	5.4

The usual procedure followed when establishing these greenhouse studies was to weigh out 26 pounds (air-dry basis) of this soil, mix the soil with an amount of fertilizer appropriate to the treatment assigned, and then place the mixture in a 2-gallon earthenware container. Test seedlings were established by planting an adequate number of run-of-the-woods seeds in each container of soil. The seedlings were thinned to a uniform stand, generally 10 per container, when satisfactorily established. Normally, the test seedlings were grown for about 10 months, the seeds were planted in early spring, and the seedlings were harvested the following winter. Soil moisture was not a limiting factor in these studies.

CSP seedlings subjected to these fertilizer treatments responded significantly (0.01 level) to the treatments applied. Top weight, root weight, and total seedling weight were significantly affected by applications of N and P. A decided NP growth interaction (significant at the 0.01 level) resulted from the applied fertilizer treatments. Total plant response of the CSP seedlings to the N and P treatments applied is shown in figure 1. Total seedling weight decreased with each added increment of N but increased as the quantity of applied P increased. Growth increased markedly when N and P were applied in combination; this was the significant NP interaction referred to above.

Potassium fertilizer applied alone or in combination with N or P has not significantly (0.01 level) influenced the growth of sand pine seedlings in these greenhouse studies. On the basis of results such as these, we have concluded that P is the major plant nutrient that is most deficient in sandhill soils such as the Lakeland series. If we intend to fertilize these soils, the P deficiency must be corrected. When this deficiency is corrected, sand pine can also be expected to respond to applications of N fertilizer.

Needle samples including both primary and secondary needles were normally collected from the seedlings produced in the greenhouse studies and analyzed for their nutrient contents by appropriate laboratory procedures. The effect of N and P fertilization on the N concentration of seedling needles is shown in figure 2. From this figure, it is apparent that as the amount of N applied alone increased, the N content of the needles also increased. Foliar N decreased as the amount of P applied alone or in combination with N increased. This decrease in the N concentration is not actually a decrease in N uptake, but rather a dilution effect resulting from the marked growth response to the N and P applied.

Phosphorus fertilization affected the nutrient concentration of the seedling needles in the same manner as did N. That is, P accumulated in the needles as the amount of P applied as fertilizer increased and decreased as the amount of N applied as fertilizer increased (fig. 3). The minimum concentration of P in the needles occurred in those seedlings grown in soil to which the maximum amount of N alone had been applied. Concentrations of P intermediate between these extremes were produced by the maximum combined applications of the N and P fertilizers included in these tests; these fertilization rates also produced the greatest growth response.

Thus, it has been demonstrated that CSP seedlings respond to the fertilizer treatments and that these same fertilizer treatments influence the nutrient concentration of seedling needles. The question naturally follows: Is there a relationship between seedling growth and the nutrient content of plant parts--in this case, the needles? To provide an answer to this questio data on seedling growth and associated concentrations of foliar nutrients from a fertilization study with CSP seedlings were grouped into seedling weight classes, and class averages were computed. These data are illustrated graphically in figure 4.

An examination of this figure shows that foliar N decreased appreciably with increased growth, with the lowest N concentration occurring in the largest seedlings. Foliar P demonstrated a concentration pattern directly opposite to that for foliar N, that is, foliar P increased as seedling size increased. This trend in foliar P concentration lends support to the previous statement that P is the nutrient element in shortest supply in soils such as Lakeland sand and is limiting to plant growth. Foliar K followed a pattern of change much like that shown by N--but to a lesser degree. The Ca concentration of these seedling needles increased with increased growth, as did foliar P, while the Mg content of the seedling needles was essentially constant over the range of seedling weight classes.

Results such as these do not permit one to state that the concentrations of N, P, etc. reported for CSP seedling needles are either critical or optimum levels for seedling growth. This is true because, by definition, the critical nutrient concentration of a plant is that concentration of a given nutrient which is just deficient for maximum growth of that particular plant (4). From figures 1 and 4, it is readily apparent that seedling growth is continuing to increase in response to the fertilizer treatments applied. A leveling off or maximum was not attained.

However, from the data on the nutrient status of the CSP seedlings in these studies, one can make statements which may serve as guidelines for judging the nutrient status either of nursery-grown CSP seedlings or of CSP plantations. Figure 1 shows a continued growth response up to the highest levels of N and P applied. If we assume size to be an indicator of plant nutrient status and maximum size to be an indicator of adequate nutrition, then from figure 4 approximate foliar values for this level of CSP seedling nutrition may be assigned as follows: N = 1.4 percent, P = 0.16 percent, K = 0.6 percent, Ca = 0.6 percent, and Mg = 0.04 percent.

PLANTATION RESPONSES TO FERTILIZATION

Fertilization of sand pine plantations is still very much in the experimental stage. Test plots have been established in plantations of both the Ocala and Choctawhatchee varieties of sand pine. These plantations were established at several locations in the northwest Florida sandhills and are representative of varying sandhill conditions. The planting sites all supported a stand of scrub oak and wiregrass prior to the establishment of the plantations. Mechanical methods of site preparation were used to eliminate this scrub vegetation. In most instances, the method employed for control of scrub vegetation was double chopping with an 11-ton, duplex brush cutter.

Seedlings for these studies were produced from run-of-the-woods seeds either by the Florida Division of Forestry or by the Southeastern Station at Marianna. Standard nursery practices such as those discussed by Sampson (3) were followed to produce these seedlings. Planting stock was 1-0 when transplanted to the test sites.

Initial spacing within each test planting was about 3.5 by 9 feet. During the third growing season after the establishment of a test, the plantation was thinned to a spacing of about 7 by 9 feet. This procedure was followed to establish uniform stand density among plots within a given test. Achieving uniform stand density within CSP plantations is relatively simple because the survival of this variety of sand pine is normally high after transplanting. It is more difficult to obtain the same uniformity within OSP plantations because this variety is more difficult to transplant.

Commercial grades of ammonium nitrate, ordinary and concentrated superphosphate, and diammonium phosphate fertilizers were used in these field tests. All fertilizers were applied with conventional farm implements. This equipment functioned satisfactorily; however, when the fertilization of sand pine is attempted on an operational basis, distribution equipment suited to conditions in rough woods should be developed if it is not already available.

The fertilization trials already established with sand pine are intended to test the following:

A. Rates of fertilizer application, with major emphasis being given to N and P

B. Methods of applying P fertilizer; that is, surface applications in contrast to various methods of mixing P fertilizer with the soil or placing it in the root zone

C. Frequency of fertilizer application; that is, comparing a single, heavy application of fertilizer with the response produced by frequent, light applications of the same fertilizer.

The oldest of these fertilization tests are located on the Chipola Experimental Forest. Prior to establishment of these test plantations, the scrub oak vegetation was removed by double chopping with an 11-ton, duplex brush cutter. Treatments that have been or will be applied to these plantations are listed in table 3.

Table 3.--Fertilization rates and methods of application

Treatment No.	Treatment applied[a]
1	None
2[b] [c]	60 lb. of P/acre applied to soil surface in strips 2.5 feet wide, rows of trees planted on center of fertilized strips
3	60 lb. of P/acre applied to soil surface in strips 5 feet wide, rows of trees planted on center of fertilized strips
4	60 lb. of P/acre applied in strips 2.5 feet wide and mixed with soil to depth of about 6 inches by disking, trees planted on center of fertilized and disked strips
5	60 lb. of P/acre applied to soil surface in strips 5 feet wide and mixed with soil to depth of about 6 inches by disking, trees planted on center of fertilized and disked strips
6	120 lb. of P/acre applied, trees planted as in 2
7	120 lb. of P/acre applied, trees planted as in 3
8	120 lb. of P/acre applied and mixed with soil, trees planted as in 4

Table 3.--Fertilization rates and methods of application (continued)

Treatment No.	Treatment applied[a]
9	120 lb. of P/acre applied and mixed with soil, trees planted as in 5
10	120 lb. of P/acre applied with a side-dressing machine to each side of row of trees and about 4 inches below soil surface, P fertilizer applied a few days after trees were planted
11	120 lb. of P/acre applied in strips 2.5 feet wide on each side of rows of trees at plantation ages 1 and 6 years, P fertilizer mixed with soil to depth of 3 inches by disking
12	120 lb. of P/acre applied as in 11 at plantation ages 2 and 7 years
13	60 lb. of P and N/acre applied as in 11 at plantation ages 1, 2, 6, and 7 years
14	40 lb. of P and N/acre applied as in 11 at plantation ages 1, 2, 3, 6, 7, and 8 years

[a] Fertilizer materials applied: N as ammonium nitrate (0-33-0) and P as superphosphate (0-20-0).

[b] For treatments 2 through 9, P fertilizer was applied a few days prior to planting.

[c] For treatments 2 through 12, an amount of N equal to the amount of P specified for a given treatment was administered in a split application: one-half was applied 1 year after a P application and the balance was applied the following year.

Growth responses to these treatments through plantation age 7 are given for OSP and CSP in table 4. Both varieties of sand pine have responded to the fertilizer treatments applied. In general, as the amount of applied fertilizer increased, growth increased but not necessarily in proportion to the increase in fertilizer application. OSP has shown a greater response in height growth than has CSP, especially to the higher rates of fertilization. Diameter growth of CSP in response to fertilization has increased more rapidly than that of OSP, with a resultant increase in total volume. Frequent, light applications of fertilizer have produced a greater growth response than a single, heavy application of the same materials. This type of response suggests a need for slow-release sources of N and P for sandhill fertilization.

Table 4.--OSP and CSP response to fertilization to age 7

Treatment No.[a]	OSP Avg. height	OSP Avg. d.b.h.	OSP Total vol./acre[b]	CSP Avg. height	CSP Avg. d.b.h.	CSP Total vol./acre[b]
	Ft.	In.	Cu. ft.	Ft.	In.	Cu. ft.
1	17.5	2.51	166	17.4	2.74	194
2	17.8	2.67	190	17.9	3.02	239
3	18.1	2.70	196	18.0	2.91	224
4	18.5	2.78	212	18.5	3.17	270
5	18.9	2.92	237	18.5	2.93	234
6	19.6	2.94	248	18.7	3.21	280
7	19.7	2.94	248	18.2	3.17	266
8	19.6	2.85	234	18.4	3.16	267
9	19.7	2.76	221	18.3	2.85	219
10	19.9	2.90	245	19.2	3.17	280
11	20.3	3.03	271	18.6	3.21	278
12	18.9	2.85	226	18.7	3.19	276
13	19.6	2.99	256	19.1	3.20	283
14	20.2	3.08	278	19.8	3.41	331

[a] See table 3 for rates and time of fertilizer application.

[b] Total volume based on 650 trees/acre.

Needle samples have been collected annually during January from a random sample of trees within each fertilization study. The needles collected have been analyzed by standard laboratory procedures to determine the concentration of N, P, etc. contained in the samples. This information is another measure of tree response to the fertilizer treatments applied and may serve as an indication of the nutrient status of these plantations.

A summary of the N and P concentrations in the needles of OSP and CSP at plantation age 7 is given in table 5. The treatment numbers in this table correspond to those given in table 3. An examination of this table shows an obvious varietal difference in the N and P concentrations in CSP and OSP needles. Both the N and P concentrations in CSP needles for all treatments applied were greater than those in OSP needles. A decided increase in the P concentrations in the needles of both varieties in response to treatments applied is evident. Of interest is the N concentration of the needles of both varieties for treatment 1, the unfertilized control. For all treatments, except treatment 7 for OSP, the N concentration of the needles of unfertilized trees was greater than that of trees that had been fertilized with both N and P. This is an example of the dilution effect noted earlier, that is, a decrease in the concentration of a given element per unit of weight as a result of increased growth. These results also illustrate the dangers of assuming that a high foliar concentration of a given element, in this case N, means that the N supply is sufficient for good growth. Also of note is the fact that, as the P concentration of the needles increased in response to fertilization, the N concentration decreased. These responses to N and P fertilization are identical to the seedling responses to these same fertilizers as discussed earlier.

Table 5.--Concentrations of N and P in needles of fertilized OSP and CSP at age 7

Treatment No.[a]	OSP		CSP	
	N	P	N	P
	Percent			
1	1.28	0.09	1.40	0.11
2	1.26	.10	1.37	.13
3	1.20	.11	1.34	.13
4	1.27	.12	1.36	.13
5	1.24	.12	1.35	.13
6	1.20	.12	1.37	.13
7	1.24	.12	1.37	.14
8	1.29	.13	1.33	.14
9	1.18	.13	1.30	.14
10	1.21	.11	1.34	.12
11	1.24	.13	1.31	.14
12	1.19	.14	1.30	.14
13	1.19	.14	1.24	.14
14	1.21	.13	1.32	.14

[a] See table 3 for rates and time of fertilizer application.

At this point we might ask if these trees are growing at optimum nutrient levels. Growth has increased as a result of fertilization. The P concentrations of the needles of these saplings have increased as a result of fertilization, but they are still lower than those values associated with maximum seedling growth as noted earlier in this paper. Mead and Pritchett (1) have pointed out that needles of older trees often contain lower concentrations of nutrients than needles of seedlings or young trees. This does not necessarily mean that lower nutrient concentrations in needles of large trees are optimum. It is quite possible that large trees are actually functioning at less than full capacity because the supply of available nutrients is inadequate to maintain optimum nutrient levels in the mass of needles found in such trees. Perhaps "optimum" nutrient levels are less dependent on tree age and more dependent on the supply of available nutrients.

An economic analysis of the fertilizer responses discussed in this paper has not been made. Even though certain fertilizer treatments have increased total volume as much as 50 to 60 percent, there seemed to be little point in extrapolating data for plantation age 7 to a rotation age of 25 years.

It is encouraging, however, to note that after 7 years the P concentrations in the needles of those trees fertilized at even the lowest rates are still substantially higher than the P concentrations in the needles of unfertilized trees. This has not been true of slash pine growing on the same soils and fertilized at comparable rates. Foliar P concentrations of fertilized slash pine have dropped to those of unfertilized slash pine over a 7-year period. Earlier in this paper, it was pointed out that sand pine must be extremely efficient at extracting essential growth elements from the soil and at maintaining a desirable internal balance of nutrients and moisture. It therefore appears entirely possible that, after a sand pine plantation has been fertilized, the trees will be capable of recycling a substantial portion of the added nutrients within the trees or stand and that tree growth will be increased for a major portion of a plantation rotation.

LITERATURE CITED

1. Mead, D. J., and Pritchett, W. L. 1971. Tree response to fertilizers in field and pot experiments. Soil Sci. Soc. Am. Proc. 35: 346-349.

2. Metz, Louis J., and Wells, Carol G. 1965. Weight and nutrient content of the aboveground parts of some loblolly pines. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. SE-17, 20 pp.

3. Sampson, Oscar R. 1973. Nursery practices used for sand pine. In Sand pine symposium proceedings 1972. USDA For. Serv. Southeast. For. Exp. Stn.

4. Ulrich, Albert. 1952. Physiological basis for assessing the nutritional requirements of plants. Annu. Rev. Plant Physiol. 3: 207-228.

5. Walker, L. C., and Youngberg, C. T. 1962. Response of slash pine to nitrogen and phosphorus fertilization. Soil Sci. Soc. Am. Proc. 26: 399-401.

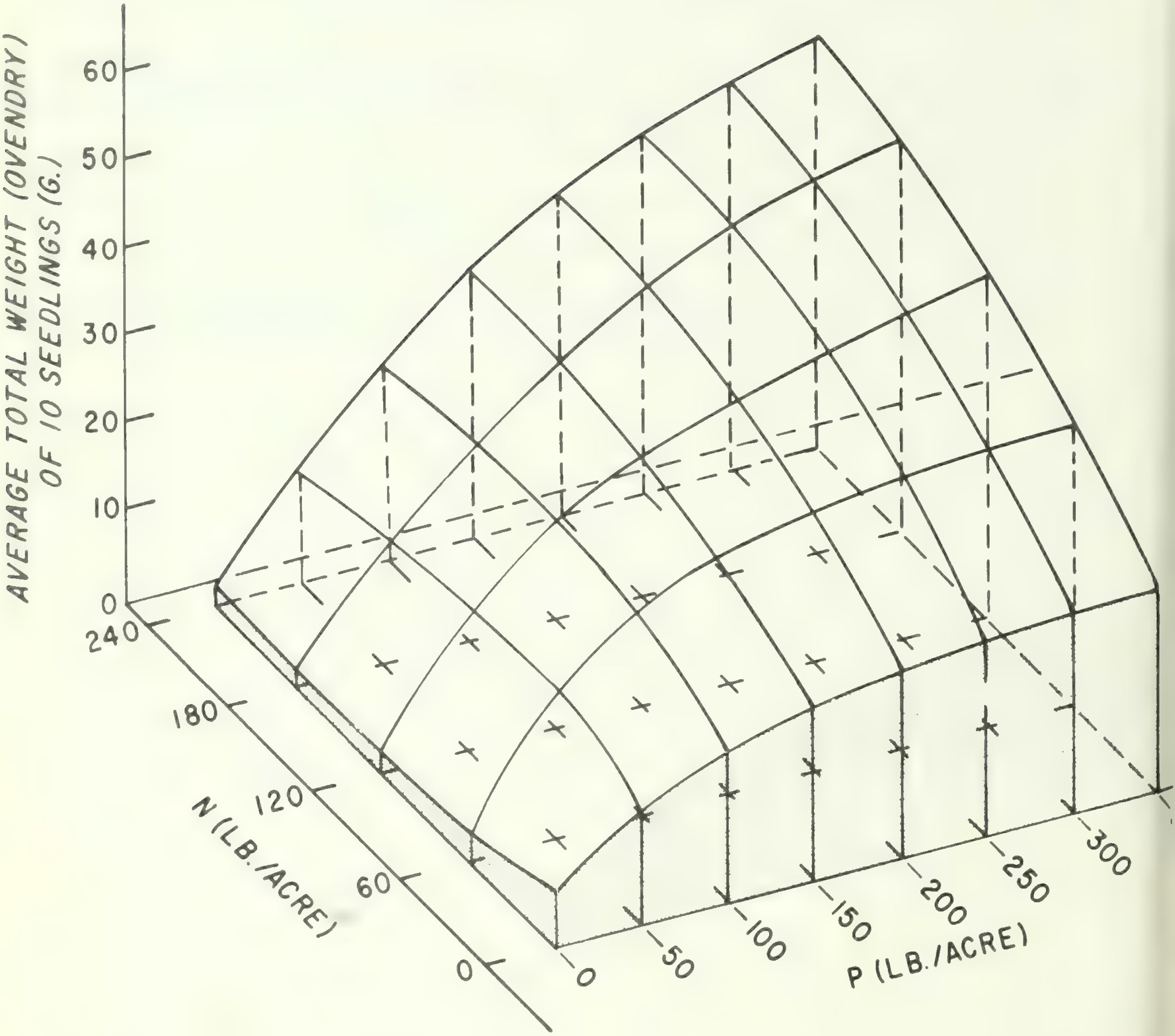

Figure 1. --Effect of N and P fertilization on average total weight (ovendry) of 10 CSP seedlings.

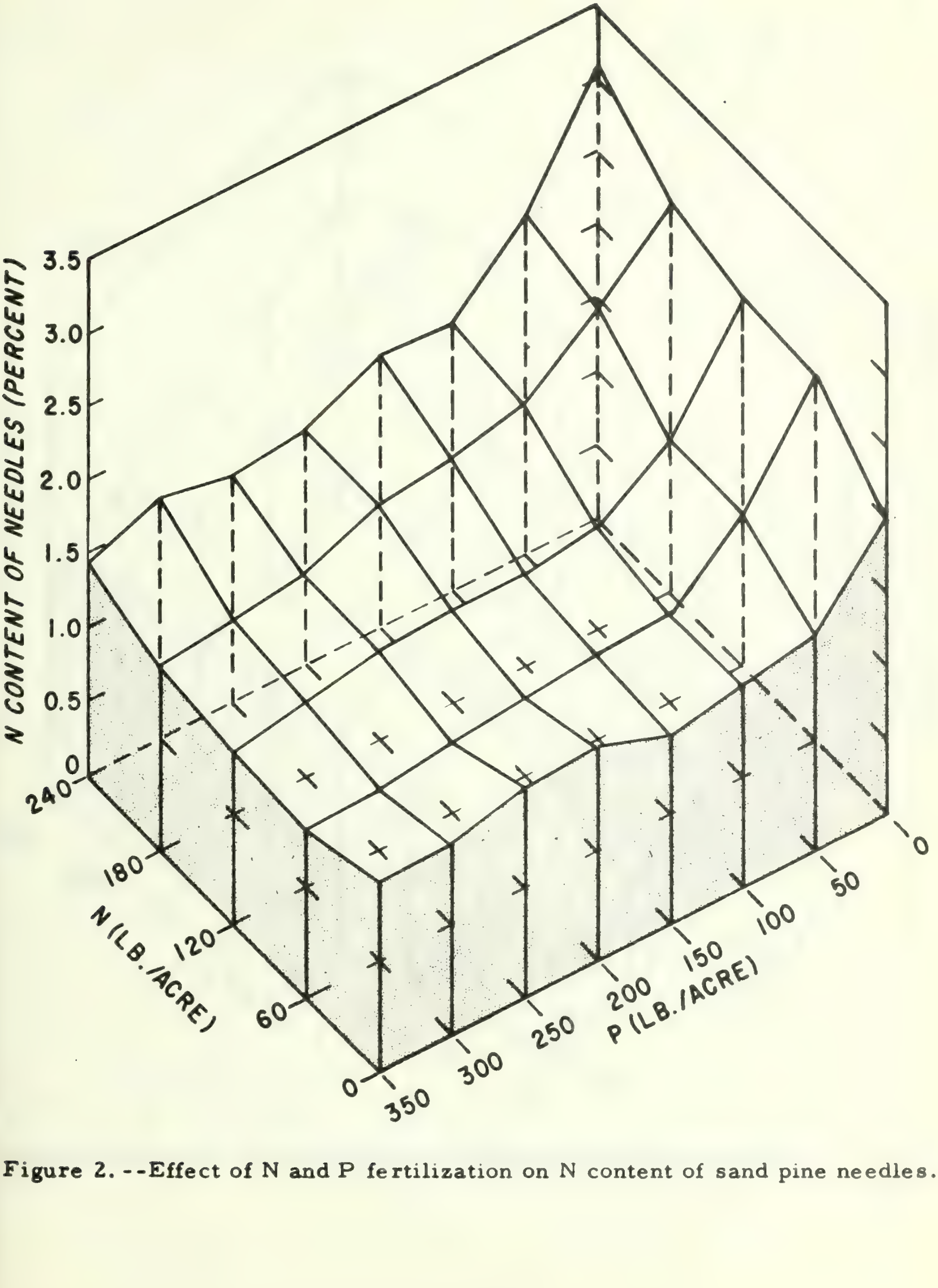

Figure 2. --Effect of N and P fertilization on N content of sand pine needles.

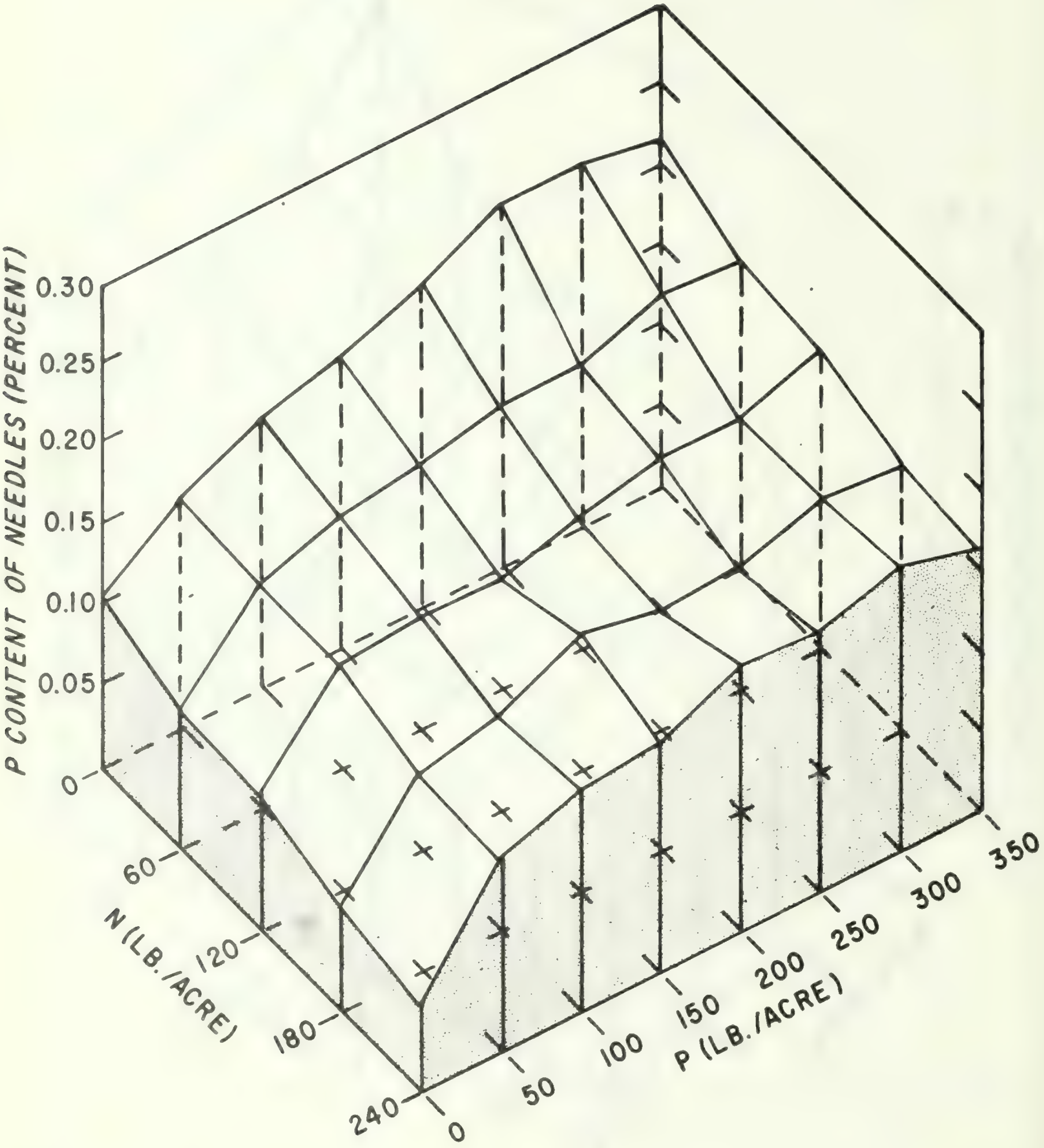

Figure 3. --Effect of N and P fertilization on P content of sand pine needles.

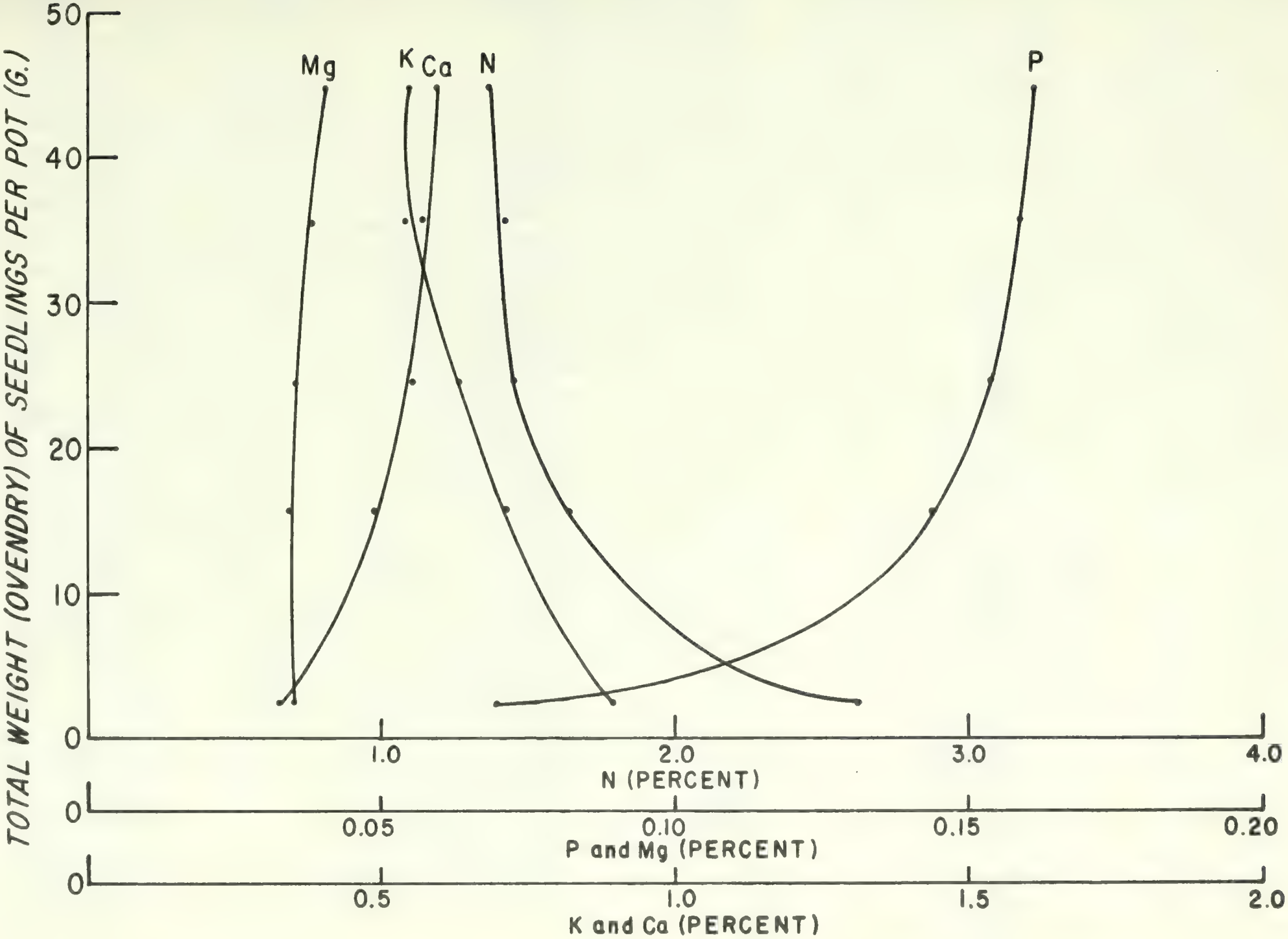

Figure 4. --Variation of total weight (ovendry) of CSP seedlings with nutrient concentration of needles.

UNDERSTORY VEGETATION, WILDLIFE, AND RECREATION IN SAND PINE FORESTS

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Abstract.--With adequate planning and integrated management, the sandhills of Florida have a potential for providing wildlife and recreational uses along with wood production. Understory vegetation in the longleaf pine-turkey oak and sand pine-scrub oak associations presently supports small populations of many wildlife species and makes these areas popular for hunting. Recreation other than hunting is also a major use of some areas.

INTRODUCTION

In forest management, it is natural to concentrate our efforts on the production of wood because this product is relatively easy to see, measure, harvest, and appreciate. It permits straightforward management practices and is readily converted into money. But we must not become blinded so that we cannot see the forest for the trees. There are other products and aspects of the forest that merit our attention.

Some of the environmental aspects of forests, such as clean air, clean water, and open space, are intangible, that is, they are hard to see or measure or harvest. Yet we know these products are becoming increasingly valuable. Other products of forests, such as wildlife, recreational areas, and understory vegetation, are more readily seen, measured, and appreciated. They, too, are increasing in value and should receive more attention in our management plans.

One approach to this task is integrated management for multiple-product yields, an approach that helps us take advantage of the total potential of the forest. Integrated management is the simultaneous, harmonious use of a resource for more than one product. Integrated management plans give full consideration to each alternative combination of products, such as wood-wildlife or livestock-timber-water or deer-pulpwood-camping-orchids. Management must consider the requirements of each product and the many interactions between products to determine the compatibility and compromises required to implement an integrated plan.

A number of forces are pushing us closer each day to integrating management of our resources. Economists tell us that we need to receive full returns from our investment, in this case our landholdings. Integrated management works on the assumption that greater benefits or returns (not necessarily financial returns) accrue with it than with single-use management. In many areas, integrated management is required by law, but more frequently we see it practiced because of personal desires of the landowner. Pressure of public demands will, no doubt, influence many managers to adopt multiple-use. Fortunately, our southern forests, including the sand pine forests, are adaptable to multiple-product management.

BACKGROUND

The sandhills in the Southeast are comprised primarily of soils from marine deposits. These soils are well to excessively drained, acidic, infertile, and thick, varying from a few feet to more than 60 feet. They extend from southwestern Alabama to the Carolinas, with an estimated 3 million acres in Florida. Moisture-holding capacity of the soils is poor, and only drought-tolerant plants are able to survive.

Repeated turpentining and cutting of timber from about 1890 to 1930 ultimately removed most of the longleaf pine (*Pinus palustris* Mill.) from the longleaf-turkey oak association. Thereafter, much of the land became dominated by scrub hardwood species such as turkey oak (*Quercus laevis* Walt.), bluejack oak (*Q. incana* Bartr.), sand post oak (*Q. stellata* var. *margaretta* (Ashe) Sarg.), and dwarf live oak (*Q. minima* (Sarg.) Small). In the sand pine-scrub oak association where sand pine (*Pinus clausa* (Chapm.) Vasey) has been removed by harvesting or fire, the area becomes dominated over long periods by scrub oaks, such as Chapman oak (*Q. chapmanii* Sarg.), myrtle oak (*Q. myrtifolia* Willd.), and sand live oak (*Q. virginiana* var. *maritima* (Michx.) Sarg.). Overall, the sandhills are a harsh environment for man's use, but there is a good mixture of other vegetation types, such as swamps, marshes, hammocks, and prairie, that provide good wildlife habitat and excellent opportunities for recreation.

Use of these harsh sites to meet man's needs for wood, wildlife, open space, clean air, clean water, and recreation requires careful management and manipulation of the soil and vegetation. Our present knowledge about understory vegetation, wildlife, and recreation on the sand pine forests of the sandhills, along with some concepts of integrated management about these areas, are the subjects of this paper.

UNDERSTORY VEGETATION

Some early descriptions and comments on the vegetation of the Florida sandhills were made by Nash (13) in 1895, Harper (8) in 1914, and Gano (2) in 1917, along with later descriptions by Mulvania (11) in 1931, Pessin (15) in 1933 and Webber (20) in 1935. More recent descriptions by Strode (18) and Harlow (5, 6) provide information for planning the use and management of these forest types. The sand pine-scrub oak and longleaf-oak uplands are typical vegetation types of the sandhills; the former is limited primarily to the Ocala National Forest, whereas the latter occurs throughout north and central Florida.

The species of plants in the understory vary with locality. Detailed locale lists may be found for north Florida in Gano (2), for central Florida in Mulvania (11) and Nash (13), and for central and west Florida in Harlow (5, 6). Pineland threeawn (*Aristida stricta* Michx.), also called wiregrass, is the principal understory herb. Other plants present in most localities are gopherapple (*Chrysobalanus oblongifolius* Michx.), saw-palmetto (*Serenoa repens* (Bartr.) Small), and goldaster (*Chrysopsis* spp.).

Forage yields from different locations and sites within the sandhills are highly variable (table 1). Except for some of the better longleaf pine sites, these dry, infertile sites offer little potential for livestock grazing or farming.

Harvesting of timber or pulpwood from the sandhills allows hardwoods and other understory plants to increase their growth rate and, frequently, to dominate the site completely. The oaks are especially efficient in this regard. Annual plants are also abundant for the first year or two after soil disturbance, and foods for wildlife increase with either thinning or complete harvesting of the timber overstory. Harlow (5) measured 435 pounds of browse per acre under a 30-year-old mature stand of Ocala sand pine, whereas production was 1,021 and 689 pounds per acre at 2 and 4 years after pulpwood harvest and brush cutting.

Table 1.--Forage yields from two types of sandhill vegetation on the Ocala National Forest, Withlacoochee State Forest, and Eglin Air Force Base, Florida[a]

Forages	Pine-oak scrub	Pine-oak uplands		
	Ocala	Withlacoochee	Eglin	Ocala
	Lb./acre			
Grasses and sedges	3	206	10	121
Forbs	10	48	2	7
Woody plants[b]	738	66	5	39

[a] Adapted from Harlow (5).

[b] Primarily green leaves.

Site preparation for planting pines is generally considered essential in the sandhills. Chopping for this purpose increased yields and numbers of species of understory vegetation on longleaf-turkey oak sites in the Apalachicola National Forest (table 2).[1] These treatments also improved wildlife habitat by providing more forage, seeds, and plant species to satisfy animal preferences. Grelen (3) found that single chopping killed few of the native plants and merely "cultivated" the oaks and pineland threeawn. However, this treatment could be very beneficial for wildlife if some reduced growth of planted pine was acceptable.

In 1955, eight site-preparation treatments were installed on the Chipola Experimental Forest in northwest Florida. Response of the pine seedlings was best on the double-chopped sites, and Grelen (4) followed species succession for 4 years. The first year after treatment, he counted 36 species in April, 50 in July, and 55 in October. The most conspicuous plant early in the year was yellow buttons (Balduina angustifolia Pursh), followed by September prairieclover (Petalostemon corymbosus Michx.) in September; two perennial grasses, a panicum (Panicum malacon Nash) and fall witchgrass (Leptoloma cognatum (Schult.) Chase), then became predominant. During the second year, numerous annuals were present, but dogfennel (Eupatorium compositifolium Walt.) was most abundant and broomsedge (Andropogon virginicus L.) began invading the area. During the fourth year, dogfennel was the herbaceous dominant and broomsedge was abundant, although Panicum malacon Nash and fall witchgrass remained the most prevalent grasses. Pineland threeawn and the hardwoods were almost nonexistent.

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[1] McDaniel, J. C. An evaluation of the effects of pine-site preparation, oak thinning, and bulldozing titi thickets on the Apalachicola National Forest. 1965. (Mimeogr. Final Rep. on Project W-41-R-13, Fla. Game & Fresh Water Fish Comm.)

Table 2. --Number of species and yields of browse and herbaceous plants after site preparation in 1958 in longleaf pine-turkey oak of the Apalachicola National Forest[a]

Treatment	1959		1961		1963		1965	
	Species	Yield	Species	Yield	Species	Yield	Species	Yield
	No. / acre	Lb. / acre	No. / acre	Lb. / acre	No. / acre	Lb. / acre	No. / acre	Lb. / acre
No treatment	19	204	20	313	16	631	19	171
Single chop	21	582	27	1,130	25	821	19	809
Double chop	22	188	30	799	24	1,361	29	714

[a] Adapted from: McDaniel, J. C. An evaluation of the effects of pine-site preparation, oak thinning, and bulldozing titi thickets on the Apalachicola National Forest. 1965. (Mimeogr. Final Rep. on Project W-41-R-13, Fla. Game & Fresh Water Fish Comm.)

Hebb (9) reported the trends concerning the important wildlife food plants on Grelen's plots for 13 years. Many species, especially the oaks, gopherapple, and grassleaf goldaster (Chrysopsis graminifolia (Michx.) Ell.), decreased, while blackberry (Rubus enslenii Tratt.), milkpeas (Galactia spp.), and dogfennel increased in number of plants (table 3). The noseburns (Tragia spp.) and broomsedge ended up with about equal numbers on chopped and unchopped plots. Overall, there was a small decrease in the number of desirable game food plants with double chopping. However, a less severe form of site preparation might have improved wildlife habitat.

It is readily apparent that man's activities influence understory conditions in the sandhills. Proper management of understory vegetation is essential for protecting watershed values while maintaining and enhancing the use of forests by wild or domesticated animals, game or nongame birds, and man in his esthetic and recreational pursuits. We have much to learn about obtaining balance between the reduction of plant competition with pines and the maintenance of desirable plants for other uses.

Table 3.--Trends in numbers of wildlife food plants after chopping in both May and September 1955 on the Chipola Experimental Forest[a]

Class and species	Chopped plots after--						Unchopped plots after 13 yr.
	1 yr.	3 yr.	6 yr.	8 yr.	10 yr.	13 yr.	
	- - - - - - - - - Thousands/acre - - - - - - - - - -						
Woody plants							
Bluejack oak	0.2	0.1	0.1	0.2	0.4	0.4	4.0
Turkey oak	2.0	.4	.4	.4	.4	.4	2.4
Dwarf live oak	.4	.8	.4	1.6	2.0	1.6	14.0
Gopherapple	6.4	3.2	2.0	4.0	5.2	7.6	23.2
Blackberry	.0	.0	.8	5.6	10.0	14.4	.0
Grasses							
Pineland threeawn	.4	.4	.2	.2	.2	.2	59.2
Broomsedge	.8	6.0	8.4	22.0	54.4	49.6	45.6
Forbs							
Goldaster	.0	.1	.0	.1	.4	.4	16.8
Milkpeas	1.2	.8	.4	2.0	2.0	4.4	1.6
Prairieclover	1.6	2.4	1.2	1.2	.8	.4	.4
Noseburn	3.6	1.2	1.6	2.0	3.2	2.8	3.6
Dogfennel	.4	32.4	8.8	26.0	19.6	6.8	.0

[a] Adapted from Hebb (9).

WILDLIFE

The sandhills provide satisfactory habitat for many species of wildlife but are unable in most instances to sustain large populations. The more common game species are deer, hogs, squirrels, rabbits, quail, doves, and ducks. Endangered and rare species found in protected sandhill areas such as Eglin Air Force Base are Florida sandhill crane (*Grus canadensis pratensis*), southern bald eagle (*Haliaeetus leucocephalus*), peregrin falcon (*Falco peregrinus anatum*), southern red-cockaded woodpecker (*Dendrocopos borealis hylonomus*), Florida panther (*Felis concolor coryi*), and American alligator (*Alligator mississipiensis*). No doubt, the interspersion of vegetation types allows wildlife species to find their favored habitat and helps maintain a varied wildlife population in the sandhills.

Although habitat requirements of each species of wildlife are different, the qualities that provide good habitat for one species are frequently important qualities to other species. When most habitat requirements of several wildlife species are present in a particular vegetation type, severe competition may develop. However, through knowledge of these habitat requirements, we can often manage the vegetation in such a way that many conflicts are minimized, if not eliminated.

Activities of man affect wildlife populations by changing habitat conditions. For example, the increasing number of white-tailed deer (Odocoileus virginianus) in the South coincided with major reforestation efforts following World War II, but bobwhite quail (Colinus virginianus) populations decreased during this period of reforestation and fire exclusion. Furthermore, clearing of land, diversification of farm crops, and rapid expansion of improved pastures for cattle have created ideal habitat for mourning dove (Zenaidura macroura) by improving sites for nesting and increasing food supplies (21).

Populations of eastern wild turkey (Meleagris gallopavo) are fairly low in those areas where sand pine predominates and water is often scarce (16). However, they are able to persist in bottom-land hardwoods along the streams and swamps that intersperse the type, and they frequently move into the upland scrub oaks. Turkeys will eat almost anything, but acorns make up a majority of their diet during the fall and winter, along with seeds and fruits of legumes, grasses, and other hardwoods as they become available during the year. Conversion of bottom-land hardwoods to agricultural cropland has reduced some prime habitat, but planting large areas to pines increases favorable habitat if several large hardwoods are left on the area. Prescribed burning in pinelands at about 3-year intervals will improve the quality of turkey habitat.

The presence of white-tailed deer has always made the sandhills a favorite hunting area, although populations are not extremely high. However, in Florida the highest deer populations occur in these areas. Strode (18) estimated that the deer population on the Ocala National Forest was one deer per 43 acres and that maximum carrying capacity was one deer per 35 acres. Harlow (5) estimated maximum carrying capacity of pure sand pine-scrub oak type to be one deer per 70 acres, but the interspersement of other vegetation types increased the overall carrying capacity. The potential carrying capacit for both pine-oak uplands and sand pine-scrub oak sandhills was estimated to be one deer per 34 acres (7). Cover for deer is generally abundant; therefore, the limiting habitat factor seems to be the amount of quality food available.

Food habits of deer in the sandhills have not been studied except during the fall-winter period, which is considered the most critical for adequate nutrition. During the fall and early winter, mast (acorns and saw-palmetto berries) are the most important deer foods throughout Florida and in the sandhills, but they are gone by late winter (fig. 1). Browse (leaves, stems, and berries of woody plants) and herbaceous material (forbs and grasses) assume greater importance as mast becomes less available. Mushrooms are used whenever available. The more important browse species are oaks, shining sumac (*Rhus copallina* L.), greenbrier (*Smilax* spp.), pine (*Pinus* spp.), ground blueberry (*Vaccinium myrsinites* Lam.), sandhill kalmia (*Kalmia hirsuta* Walt.), and garberia (*Garberia fruticosa* (Nutt.) A. Gray).

Management practices that will maintain or improve deer habitat in the sandhills are oriented around the need to maintain enough oaks to provide acorns and browse. Where timber stand improvement is practiced, about 5 to 10 large, mature oaks per acre should be left alive (18). Pulpwood harvest should be in small blocks (20 to 100 acres) that are well scattered over the forest. Wherever possible, prescribed burning every 3 or 4 years will improve quality and availability of browse.

Beckwith (1) found that, when preparing sandhill sites for planting pine, strips of oaks should be left throughout the planting area. Leaving 10-chain-wide strips of undisturbed land every 10 or 30 chains in a mile resulted in better deer use of cleared areas in central Florida than when square-mile blocks were totally cleared. Site preparation consisted of chaining to remove the large trees and then chopping after 4 to 6 weeks to kill the lesser vegetation. Deer made heaviest use of the cleared strips in the spring, about equal use of cleared and uncleared areas in the summer, and heaviest use of uncleared areas in the fall. This pattern seemed to coincide with availability of succulent forage and acorns.

Bobwhite quail populations are fairly low in the sandhills, but Stoddard (17) believed that such country could produce quail in abundance when cultivated to remove the dominance of scrub oak and wiregrass. Murray and Frye (12) also considered the rolling sand pinelands of the longleaf pine-turkey oak association to be major quail habitat in Florida, particularly when succession is set back by burning, chopping, or disking, each of which produces a greater abundance of seed-producing forbs and grasses. Native plants frequently used as quail foods in northwest Florida in the winter are acorns, tickclover (*Desmodium* spp.), common lespedeza (*Lespedeza striata* (Thunb.) H. & A.), partridgepeas (*Cassia* spp.), milkpeas, flowering dogwood (*Cornus florida* L.), bull paspalum (*Paspalum boscianum* Flugge), and pine seed.

Many wildlife species are naturally at home in the sandhills. If given some management consideration, they should find desirable habitat in sand pine forests and increase the benefits and productivity of this resource.

RECREATION

During the last two decades, the availability of more leisure time, less strenuous work, greater affluency, and greater ease of travel have resulted in a boom in recreational activities. Strohm (19) recently reported some statistics from the Bureau of Outdoor Recreation which show the following participation of Americans in various outdoor activities:

Activity	People (millions)	Activity	People (millions)
Picnicking	82.1	Camping	35.2
Swimming	77.3	Nature walks	30.5
Walking for pleasure	50.3	Hunting	20.9
Fishing	49.4	Horseback riding	16.1
Boating	41.4	Bird watching	7.5
Bicycling	37.1	Wildlife photography	4.9

Frequently, the demand for recreational areas and facilities exceeds the supply. It has become necessary to begin limiting the number of visitors to some of our larger recreational areas, such as National Parks and Wilderness Areas. These increasing needs prompt us to look at some rather inhospitable areas, such as the sandhills of the Southeast, for opportunities to create additional recreational facilities.

The Ocala National Forest in central Florida, our largest single expanse of sand pine-scrub oak, has for years been a popular recreational area. James and Harper (10) reported that 1.2 million visits in one year resulted in 24,212,639 man-hours of recreational use, with the following breakdown:

Activity	Man-hours (millions)	Activity	Man-hours (millions)
Camping	7.6	Sightseeing	1.2
Recreation residences	7.4	Swimming	1.1
Fishing	2.7	Picnicking	.5
Hunting	3.0	Boating, hiking, etc.	.5

The intensity of use on this area has increased over the years. With the opening of Disney World, the demands have accelerated and, no doubt, will continue to do so.

Another example of effective planning and use of the recreational potential in the sandhills is Eglin Air Force Base in the Florida panhandle (14). Military installations have programs in the management and conservation of natural resources to guide the use of land not directly used in the military mission. Generally, development of recreational areas has received emphasis. For example, Eglin Air Force Base encompasses 460,320 acres, with 406,000 acres being forested and about 264,000 acres open for hunting. Some 34 ponds and lakes are stocked and managed for fishing; these are used to supplement fishing on 150 miles of natural streams. Other recreational opportunities are provided by 50 picnic tables, 8 miles of bridle paths, and 3 miles of hiker trails. About 1,000 acres are planted with supplemental foods for wildlife. A checklist of over 400 birds identified on Eglin is also provided for birdwatchers.

In 1970, 2,326 fishermen purchased permits to fish on Eglin, and 8,551 hunters were provided over 100,000 man-days of hunting. Harvested were 2,206 deer, 299 hogs, 3,462 quail, 16,335 doves, 22,566 squirrels, 1,512 ducks, and many tons of fish.

These examples illustrate opportunities and successful attempts for recreational use of the sandhills. The recreational and wildlife potentials can become reality if integrated management is practiced as greater areas of the sandhills are converted from scrub oak to sand pine. In these efforts to integrate management, we need to be constantly aware of natural beauty and attempt to duplicate it. For example, when rows of trees are planted or strips of oaks are left, straight lines should be avoided in favor of meandering, naturalistic patterns. Roads should be paralleled and land or water contours should be followed. It must be remembered that scenery is also a forest value.

CONCLUSIONS

The sandhills offer good potential for development of recreational opportunities and increased wildlife populations through effective management of the understory vegetation. But we have much to learn about good manipulation of vegetation, especially as related to sand pine, because no detailed studies have been made of understory vegetation under planted stands. Because sand pine can compete successfully when planted in native vegetation and also responds to site preparation, our research will be concentrated on how sand pine and the understory respond when this pine is planted in native vegetation and on how they respond to varying levels of site preparation.

If pines are planted in narrow, chopped rows amid intervening, unchopped strips of varying widths, we have the opportunity of achieving increased growth of pines and maintaining much of the native vegetation while decreasing the cost of site preparation. These prepared rows can also be planted with supplemental wildlife foods. If fertilization is limited to the rows of trees, greater response by the trees or planted understory will be achieved. Techniques for prescribed burning of sand pine for the improvement of wildlife habitat also need to be developed.

LITERATURE CITED

1. Beckwith, S. L. 1967. Effect of site preparation on wildlife and vegetation in the sandhills of central Florida. Eighteenth Annu. Conf. Southeast. Assoc. Game & Fish Comm. Proc. 1964: 1-10.

2. Gano, L. 1917. A study in physiographic ecology in northern Florida. Bot. Gaz. 63: 337-372.

3. Grelen, H. E. 1959. Mechanical preparation of pine planting sites in Florida sandhills. Weeds 7: 184-188.

4. ____________ 1962. Plant succession on cleared sandhills in northern Florida. Am. Midl. Nat. 67: 36-44.

5. Harlow, R. F. 1959. An evaluation of white-tailed deer habitat in Florida. Fla. Game & Fresh Water Fish Comm. Tech. Bull. 5, 64 pp.

6. ____________ 1965. Range characteristics and carrying capacities, pp. 13-44. In The white-tailed deer in Florida. Fla. Game & Fresh Water Fish Comm. Tech. Bull. 9.

7. ____________ and Jones, F. K., Jr. 1965. Deer herd dynamics and populations, pp. 58-73. In The white-tailed deer in Florida. Fla. Game & Fresh Water Fish Comm. Tech. Bull. 9.

8. Harper, R. M. 1914. Geography and vegetation of northern Florida. Fla. Geol. Surv., Sixth Annu. Rep., pp. 163-437.

9. Hebb, E. A. 1971. Site preparation decreases game food plants in Florida sandhills. J. Wildl. Manage. 35: 155-162.

10. James, G. A., and Harper, R. A. 1965. Recreation use of the Ocala National Forest in Florida. Southeast. For. Exp. Stn., U. S. For. Serv. Res. Pap. SE-18, 28 pp.

11. Mulvania, M. 1931. Ecological survey of the Florida scrub. Ecology 12: 528-540.

12. Murray, R. W., and Frye, O. E., Jr. 1957. The bobwhite quail and its management in Florida. Fla. Game & Fresh Water Fish Comm. Game Publ. 2, 55 pp.

13. Nash, G. V. 1895. Notes on some Florida plants. Torrey Bot. Club Bull. 22: 141-161.

14. O'Keefe, T., and Maxwell, J. C. 1970. Natural resources management and conservation report. U. S. Dep. Def. Eglin Air Force Base Rep., 53 pp.

15. Pessin, L. J. 1933. Forest associations in the uplands of the lower Gulf Coastal Plain (longleaf pine belt). Ecology 14: 1-14.

16. Powell, J. A. 1965. The Florida wild turkey. Fla. Game & Fresh Water Fish Comm. Tech. Bull. 8, 28 pp.

17. Stoddard, H. L. 1931. The bobwhite quail. Its habits, preservation and increase. 559 pp. New York: Charles Scribner's Sons.

18. Strode, D. D. 1954. The Ocala deer herd. Fla. Game & Fresh Water Fish Comm. Publ. 1, 42 pp.

19. Strohm, J. 1972. What do you do? (Editorial) Natl. Wildl. 10(5): 3.

20. Webber, H. J. 1935. The Florida scrub, a fire-fighting association. Am. J. Bot. 22: 344-361.

21. Winston, F. A. 1954. Status, movement and management of the mourning dove in Florida. Fla. Game & Fresh Water Fish Comm. Tech. Bull. 2, 86 pp.

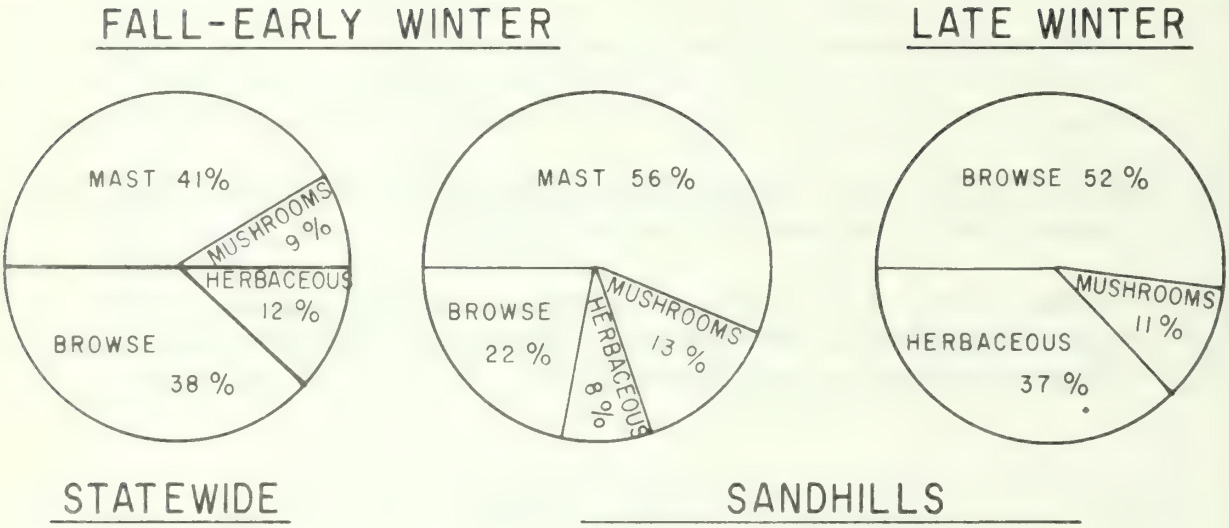

Figure 1.--Percentage breakdown of categories of food eaten by white-tailed deer in Florida from November through February, as based on stomach contents. Browse was primarily leafy material. [Adapted from Harlow (5, 6).]

INSECTS OF FLORIDA'S SAND PINE

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Abstract.--Life cycles and characteristic damage to sand pine in Florida are summarized for the following insects: bark beetles, black turpentine beetles, twig beetles, ambrosia beetles, reproduction weevils, deodar weevils, pine sawflies, pine webworms, pitch moths, tip moths, sand pine geometrids, pine pitch midges, aphids, and scales. Bark beetles, reproduction weevils, and sawflies will probably cause the greatest losses to Florida plantations of sand pine in the future.

Many species of insects attack and kill, deform, or cause growth loss to sand pine. Most of these pests are found throughout the range of sand pine, but a few are restricted to limited areas. The majority of these pests also attack the other species of pine in Florida.

The emphasis on sand pine in recent years has been spectacular--from a weed to a valuable tree. In many areas of the State it is the only tree suitable for planting, as we have learned. Much research has been undertaken to determine the proper methods of growing and managing this tree; however, research on the destructive insect and disease pests has lagged far behind.

What are the occurrences and potentials of sand pine insects? Over the past several years I have observed insects associated with this species throughout the State, but by no means would I say the following list is complete.

1. Bark beetles: Ips calligraphus (Germar), I. grandicollis (Eichh.), and I. avulsus (Eichh.). All three species have been found attacking and killing sapling-sized to mature sand pines. The first two species are much more commonly found, and normally attack the upper and lower trunk of the tree. I. avulsus normally attacks the crown area of the tree. The life cycle, from egg to adult, requires as little as 25 days in summer. Winter weather conditions can restrict development activity, and a generation may require as much as $2\frac{1}{2}$ months. It is possible to have as many as six to eight generations each year when conditions are favorable. Stress factors, such as drought, flooding, construction work, mechanical damage, lightning, fire, and crowded stand conditions, are necessary for epidemics to develop. Summer thinnings have frequently been accused of causing Ips attacks, but observations indicate otherwise. I feel you can harvest safely and selectively if soil moisture is normal and logging is done carefully. Selective harvesting may be essential if root rot is a serious problem. Keeping a healthy forest is the cheapest and most practical way to prevent losses. During outbreaks of bark beetles, salvage the infested areas, if practical, for monetary return and reduction of beetle populations. The use of pesticides may be necessary under certain conditions, either in combination with salvage or alone. The smaller sized trees can also be shredded.

2. Southern pine beetle, Dendroctonus frontalis (Zimmerman). I want to mention this insect even though it has not been reported infesting sand pine. The beetle readily attacks Virginia pine and would, I suspect, be adaptable to sand pine.

3. Black turpentine beetle, Dendroctonus terebrans (Olivier). This insect attacks larger sand pine, but apparently prefers other pine species. The life cycle requires approximately 3 months to complete, and three or four generations a year are possible. Again, the previously mentioned stress factors are very important in causing attacks. Black turpentine beetles will be present and usually in direct competition with Ips, although their activity is normally confined to the lower 6 to 8 feet of the trunk of the tree. During outbreaks, salvage the infested trees when possible. Insecticides are usually effective in controlling this beetle because of its longer life cycle and can be used alone or in conjunction with salvaging.

4. Twig beetles, Pityophthorus sp. These very small (1/16 inch) scolytid beetles are secondary pests that normally attack dead and dying

twigs. I have observed them attacking apparently healthy sand pines 1 and 2 inches in diameter and causing mortality. I believe stress factors were present that had severely weakened the trees. Grafted scions in nurseries have also been attacked and killed by these beetles. The life cycle is completed in 6 to 8 weeks. Controls under woodland conditions are impractical, but high-value seedlings can be protected with insecticides.

5. Ambrosia beetles, *Platypus* sp. These insects attack trees that are dead or dying and only use the tree for rearing young. They do not feed on any part of the tree, but carry a fungus on their bodies that they culture for the larvae. Piles of fine sawdust at the base of the tree indicate their presence. They will be found in trees infested with *Ips* and black turpentine beetles. No controls are practical for this pest.

6. Reproduction weevils, *Pachylobius picivorus* (Germar) and *Hylobius pales* (Herbst). Both of these weevils are primary killers of seedling and small sapling-sized pines. The larvae develop in the stumps and large roots of recently harvested or killed trees; they require about 6 months for their life cycle. There are two generations each year in Florida. The adults attack natural or planted seedlings in the general area. Serious problems have occurred in recent years with block cutting of other pine species. The weevils develop, emerge, and then fly to adjacent young plantings where they cause severe feeding damage and mortality. Delaying planting in harvested areas for 9 to 12 months will easily prevent attacks and economic losses. Insecticides applied as seedling dips or by spraying after the trees are planted give very effective control. Another limiting factor is that larger stumps and roots are required for successful development of the weevil. As we practice shorter rotations, suitable host material may not be present, and the weevil problem may be eliminated or greatly reduced.

7. Deodar weevil, *Pissodes nemorensis* (Germar). This weevil has attacked small sapling-sized trees that have been weakened by one or more stress factors. It is considered a secondary pest at this time and no control is practical. It has one generation a year in Florida.

8. Pine sawflies: a blackheaded pine sawfly, *Neodiprion excitans* (Rohwer); a redheaded pine sawfly, *Neodiprion lecontei* (Fitch); and a sand pine sawfly, *Acantholyda circumcincta* (Klug). These insects attack sand pine; however, the first two normally prefer other species of pines. The third appears to be an exclusive sand pine feeder. All three species attack small sapling-sized to mature timber. The *Neodiprion* species have three to five generations per year, whereas the sand pine sawfly has only one. *A. circumcincta* is known to occur only on the Choctawhatchee variety of sand pine, and to date has been found only in Walton and Okaloosa Counties in northwest Florida. In general, sawflies do not kill the trees, although there have been some notable exceptions, and natural enemies usually bring outbreaks under control in one or two generations or in 1 year. Growth loss appears to

be the major problem and approaches 90 percent in severe infestations. Several chemicals give excellent control of the larvae stage, particularly in the early instars. Research is being conducted on bacterial and viral diseases used as sprays to control the sawflies. The sawflies are quite cyclic and will be a serious, usually local, problem for 1 year and then disappear for several years.

9. Pine webworm, Tetralopha robustella (Zeller). This pest primarily attacks 1- and 2-year-old seedlings, but it will infest saplings on occasion. Some growth loss is sustained, and seedlings are occasionally killed. Sometimes, large planted areas will be severely infested and others nearby very lightly infested. Frequently, after a large infestation in 1-year-old seedlings, very few or no attacks may be found the succeeding year. Multiple generations a year occur in Florida. Egg laying takes place on the needles, and temperature determines the incubation period of the eggs. Hatching may be prolonged if cool weather persists. The larvae feed on the needles and start constructing the frass and webbing mass on the seedlings. Chemical controls are usually not necessary under forest conditions, but may be required in nurseries or special plantings. Several insecticides will give excellent control.

10. Pitch moth, Dioryctria amatella Hulst. Usually this insect is associated with tree wounds, although attacks have become more common in seed orchards during the past few years. I believe that fertilization programs have accelerated tree growth and successful attacks are occurring at the junction of the trunk and branches. The Ocala variety appears to be more susceptible, and some mortality has occurred. The pitch mass is similar to that of the bark beetles, but very much larger. The larvae feed in the phloem beneath the bark, usually adjacent to the tree wound. The larval gallery has an irregular shape and may be several inches in length. The mature larvae pupate in the resinous mass, usually in the areas of original infestation, and just prior to adult emergence, work their way near the surface of the pitch mass. Some larvae pupate and emerge as adults in a short period of time, and others will be inactive for several months before pupating. In Florida there are three to four generations each year. Control measures are usually impractical under forest conditions. Infested trees of high value, such as those in seed orchards or genetic studies, should be treated if infested, particularly when the trees are small. Several insecticides will give excellent control.

11. Tip moths, Rhyacionia spp. These insects readily attack sand pine and cause severe damage and dieback to terminals and lateral twigs. Observations indicate that no lasting deformity occurs and only a negligible amount of height growth is lost. Losses of conelets in seed orchards are high, however. Attacks normally cease after the tree reaches a height of 10 to 15 feet. Browning and dying of the infested twigs is usually the first noticeable sign of attack, and close examination of the shoots will reveal an accumulation of resin and fine webbing. When the infested shoots or buds

are broken open, the larvae or pupae may be observed or empty pupal cases will be present if the adult moths have emerged. In Florida, the adult moths mate and egg laying usually begins during the early spring. Temperature determines the incubation period of the egg, and hatching may be prolonged if cool weather persists. The newly hatched larvae feed on the new growth for a short time before boring into the shoot. The larvae continue to feed inside the shoots until they reach maturity and then pupate. Four or five generations occur in Florida each year; most twig damage and the largest populations occur during the first two generations. Control measures are usually impractical for large acreages of planted pines. However, when severe and repeated infestations occur for 2 or 3 years, chemical controls may be desirable. Trees of high value in seed orchards and in genetic studies should probably be protected. If chemical controls are used, the most important consideration is the timing of the spray application. The insecticide should be applied when hatching of the eggs occurs, so that the young larvae are subjected to a lethal dose of poison before entering the shoot.

12. Sand pine geometrid, Nepytia semiclusaria (Walker). This insect has been observed feeding on seedling, sapling, and pole-sized sand pine in central Florida. Feeding was confined to the previous year's foliage, and no mortality was observed. One generation per year is produced, and the life cycle is completed in approximately 2 months.

13. Pine pitch midge, Retinodiplosis retinodiplosis (O.S.). The adult flies are delicate, grayish-brown insects approximately 1/8 to 1/5 inch long and resemble mosquitoes in form. The mature larvae are reddish orange, about 1/4 inch long, with an indistinct head at the pointed end of the body. In the spring the female flies lay their eggs on the twigs, and the larvae begin feeding on the tender tissues. This feeding causes the resin to flow and results in pitch masses. The larvae continue to feed on the tender tissues, then mature and pupate in the pitch mass. No apparent damage occurs to the trees when attacked by this pest. One and possibly two generations occur in Florida. No insecticide controls are recommended.

14. Aphids and scales. Several species of aphids and scales have been observed on sand pine. Large populations frequently occur on individual or small groups of trees. No tree mortality has been observed, but some growth loss certainly occurs. Several generations are present each year, but natural enemies normally keep populations in check. Aphids are mobile and feed by sucking plant juices from the tender, succulent tissue and cause stunting or distorted, chlorotic needles. Scales differ in that they attach themselves to the plant and become immobile after the first nymphal or crawler stage. Heavy infestations of either insect are sometimes first detected by the presence of black sooty mold, a saprophytic fungus growing on the "honeydew" secreted by the insect. No chemical controls are recommended except, possibly, for high-value trees that are severely infested.

These insects may become more serious in the future and may also be capable of transmitting some tree diseases.

DISCUSSION

After discussing several of the insects that occur on sand pine, you might ask, "What species are economically important and how will they influence future management practices?"

1. Bark beetles, both Ips and the black turpentine beetle, will probably cause the most volume loss.

2. Reproduction weevils will be important, but losses will depend on the management practices used.

3. The various species of sawflies will be most important from the standpoint of growth loss. New species of insects that adapt to sand pine may be destructive tree killers, as recent observations seem to indicate.

4. Aphids, scales, and mealy bugs may also contribute significant growth loss, but no detailed research has been undertaken to date.

The other insects listed can be considered as minor in importance. I suspect conditions will change if a monoculture develops, and any of the already-known pests could change their habits and become destructive. Also, pests not presently attacking sand pine could adapt if conditions became favorable. It is also possible that a minor insect could well be an important vector of a serious disease.

In closing, I would like to stimulate some advanced planning, so that we can avoid crisis answers and crash programs. Insect research is necessary if we are serious about intensive management of sand pine. Very little research has been done, and I feel that many questions need answers. Research will require certain procedures and time to: (1) properly identify the pests, (2) measure their impact on trees, (3) determine their life cycles and behavior, (4) evaluate their insect enemies and other natural control factors, and (5) develop practical pest management methods that are effective, inexpensive, and safe. If we are serious about sand pine, we should begin now.

IMPORTANT DISEASES OF SAND PINE

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Abstract.--Important diseases of sand pine in the nursery include black root rot and nematodes. Diseases in plantations include Clitocybe tabescens, Phytophthora cinnamomi, and Fomes annosus. As sand pine is planted farther from its native range, new disease problems will probably arise.

INTRODUCTION

The increasing popularity of growing sand pine (Pinus clausa (Chapm.) Vasey) for pulpwood in the South has focused attention on the pathology of this species. The past history of sand pine suggests few serious disease problems. Most records and observations of the incidence of disease were made in natural stands where enphytotic conditions exist. Where pathogens and their hosts have existed together for many years, disease conditions usually are stabilized and severe epiphytotics are rare. Hence, generally innocuous diseases such as needle rust (Coleosporium vernoniae (B. & C.), needle casts (Hypoderma (syn. Ploioderma) lethale Dearn. and Hypoderma (syn. Ploioderma) hedgcockii Dearn.), twig blight (Atropellis tingens Lohm. & Cash), and eastern gall rust (Cronartium quercuum (Berk.) Miy. ex Shirai) dominate most of the early reports (7). A root and butt rot caused by Polyporus schweinitzii Fr. and heart rot caused by Fomes pini (Thore) Lloyd have been reported occasionally in sand pine; the latter usually is not a problem until the stands are more than 40 years old (7).

NURSERY PROBLEMS

Black Root Rot

Potentially, the most serious disease problem of sand pine seedlings in the nursery is black root rot caused by a complex of organisms involving Sclerotium bataticola Taub. and Fusarium spp. (6, 8). Rowan (19) established the susceptibility of sand pine seedlings to black root rot in a greenhouse study. However, this disease should pose no problem to the production of nursery seedlings because it can be easily controlled by soil fumigation. Smalley and Scheer (21) reported symptoms of black root rot in 2- to 3-year-old plantations of sand pine in west Florida. I have found occasional mortality with symptoms similar to those of black root rot in recent investigations of 1- to 3-year-old plantations, but the problem does not appear to be severe or widespread.

Nematodes

Nematodes may cause some damage to sand pine seedlings in nurseries. Hopper (9) reported that Meloidodera floridensis Chitwood, Hannon, & Esser caused severe injury and mortality to sand pine seedlings in a Forest Service nursery at Olustee, Florida. Ruehle (20) found that both the Ocala and the Choctawhatchee varieties of sand pine seedlings are susceptible to the lance nematode (Hoplolaimus galeatus (Cobb) Thorne). As with black root rot, soil fumigation should easily control nematode problems in nurseries. Although further investigations are needed, past history suggests that nematodes will not cause severe problems in plantations.

IMPORTANT DISEASES IN SAND PINE PLANTATIONS

Clitocybe tabescens

In 1956, Rhoads (12) reported Clitocybe tabescens (Fr.) Bres. as a killing root rot of sand pine in Brevard and Lake Counties, Florida. Since then, poor survival and high mortality in plantations of Ocala sand pine have been reported (1). I have examined a number of plantations of Ocala and Choctawhatchee sand pines in Georgia and Florida; up to 39 percent of some plantings of the Ocala variety were killed or infected by C. tabescens, but only minimal losses occurred in plantings of the Choctawhatchee variety (15).

A greenhouse study was therefore established in Athens, Georgia, to determine the susceptibility of the two varieties of sand pine to C. tabescens. Seedlings were grown in a fumigated medium of sand, sandy loam soil, and pine bark (1:1:1) until the stem diameter at the soil line reached 3 to 5 mm. and the height was 20 to 30 cm. Seedlings were then inoculated by cutting away a narrow 1-inch strip of bark to cambial depth at the root collar and attaching over the wound a piece of oak wood (3 to 4 cm. by 10 cm.) on which C. tabescens had been growing for 6 months. Inoculated seedlings were repotted with the attached inoculum buried in the soil medium. Within 3 to 4 weeks, high rates of mortality occurred in both varieties of inoculated sand pine and in the noninoculated controls. No evidence of infection by C. tabescens could be found in any of the seedlings. Isolations from the soil medium with a modified Kerr's medium (5) and from feeder roots of the seedlings with the apple technique (2) consistently yielded Phytophthora cinnamomi Rands. The study was inconclusive.

Another study was therefore designed to determine the susceptibility of both varieties of sand pine to C. tabescens and the virulence of different isolates of the pathogen. Three hundred 1-0 seedlings of each variety from the Chipola Experimental Forest Nursery were planted in 6-inch clay pots in a steam-sterilized sandy soil from Geneva, Georgia. These seedlings were inoculated in the same manner as described in the first study except that four different isolates of C. tabescens, numbers 188, 190, 193, and 200, were included. Except for isolate 193, which was collected from infected slash pine (Pinus elliottii Engelm. var. elliottii), all of the isolates were collected from infected root tissue of Ocala sand pine. Isolate 188 was collected from Bunnell, Florida, isolate 190 from Darien, Georgia, isolate 193 from Geneva, Georgia, and isolate 200 from Eglin Air Force Base, Florida. Mortality, apparently caused by C. tabescens, began 6 weeks after inoculation. Eighteen months after inoculation, the seedlings apparently killed or infected by C. tabescens were tabulated (table 1). Up to 7 months after the beginning of the experiment, only one cut (but noninoculated) control seedling of each variety was lost to mortality from an undetermined cause. After 8 months, however, necrosis of the feeder roots and a high percentage of seedling mortality which could not be attributed to C. tabescens occurred in both varieties. Large populations of P. cinnamomi were again isolated from the roots and from soil surrounding the roots of dead seedlings and those exhibiting symptoms of the disease. This finding, of course, reflects upon the validity and significance of the data in table 1. Because no attempt was made to detect P. cinnamomi early in the experiment, it could not be determined at what point or to what extent this organism affected the seedlings. Again, the study had to be abandoned with inconclusive results. These results do suggest that the Ocala variety is more susceptible to infection by C. tabescens and that some isolates of the pathogen are more virulent than others. However, I cannot explain the contamination by P. cinnamomi, as it could not be isolated from the potting soil or the nursery soil where the seedlings were grown. Although precautions were taken to prevent contamination, it is possible that inoculation occurred when pots were moved to an outdoor lath house 4 months after establishment of the study.

Table 1. --Percent of seedlings of Ocala and Choctawhatchee sand pine killed or infected by Clitocybe tabescens 18 months after inoculation

Isolate No.	Ocala		Choctawhatchee	
	Dead[a]	Infected[b]	Dead[a]	Infected[b]
	Percent			
188	24.4	11.0	11.0	15.5
190	4.4	17.7	2.2	2.2
193	4.4	15.5	0	4.4
200	2.2	8.8	0	0

[a] A seedling was considered to have been killed by C. tabescens if the perforate mycelial mat or the black xylostroma of the organism was present on the stem or roots.

[b] A seedling was considered to be infected by C. tabescens if it was still living but had no (or incomplete) callus formation around the wound, copious resin exudation from the wound, soaking of stem or root wood, and necrotic tissue around the wound at the point of inoculation.

Phytophthora cinnamomi

Phytophthora cinnamomi is widespread throughout the South and Southeast (3, 4). The involvement of this pathogen in the etiology of the littleleaf disease has been well-documented (3). Mortality of Douglas-fir seedlings and ornamental plantings in the Pacific Northwest has been attributed to P. cinnamomi, but serious problems are not expected in forest stands in that region because of the pathogen's apparent inability to withstand the climatic extremes (10, 18). Ross and Marx (17) proved that P. cinnamomi is a virulent pathogen on both varieties of sand pine seedlings. Because P. cinnamomi had never been associated with decline and mortality of sand pine in the field, we collected soil samples from eight locations in Florida and Georgia. Natural and planted stands of both varieties of sand pine were sampled in areas where trees had been killed by C. tabescens and also in disease-free areas. We found P. cinnamomi in soils from four of seven plantations where mortality and C. tabescens were present, but we did not find it in natural stands (table 2).

Table 2.--Recovery of Phytophthora cinnamomi from soils in planted and natural stands of Ocala and Choctawhatchee sand pine

Location of stand	Variety of sand pine[a]	Type of stand[b]	Mortality and Clitocybe tabescens present	P. cinnamomi recovered in air-dried soil
				Maximum propagules/g.
Eglin AFB Reservation				
Stand 1	O	P	Yes	1.8
Stand 2	C	P	No	0
Stand 3	O	P	No	0
Stand 4	C	N	No	0
Stand 5	C	N	No	0
Chipola Experimental Forest				
Stand 1	C	P	No	0.6
Stand 2	C	P	No	0
Stand 3	O	P	Yes	0
Bristol, Fla.				
Stand 1	O	P	Yes	0
Stand 2	C	P	No	0
Panama City, Fla.	C	N	No	0
Ocala National Forest				
Stand 1	O	N	No	0
Stand 2	O	N	No	0
Yulee, Fla.				
Stand 1	O	P	Yes	3.0
Stand 2	O	P	Yes	5.2
Darien, Ga.	O	P	Yes	0.8
Geneva, Ga.	O	P	Yes	0

[a] O = Ocala; C = Choctawhatchee.

[b] P = planted; N = natural.

These findings do not prove conclusively that P. cinnamomi is a pathogen of sand pine under field conditions. However, the proof of its pathogenicity on seedlings in the greenhouse, as well as its association with areas where mortality of sand pine was attributed to C. tabescens, strongly suggests its involvement in the etiology of the root disease complex.

Fomes annosus

Root rot caused by Fomes annosus (Fr.) Karst. has become a serious problem in planted pines in the United States over the past 20 years. A 1960 survey revealed high percentages of infection in thinned plantations of slash and loblolly pines (11). Freshly cut stumps left in thinning operations have been recognized as the primary pathway by which F. annosus enters and causes mortality in the residual stand (13). I reported sand pine as a new host of F. annosus root rot in 1968 (14). This serious root disease of other southern conifers was not a problem in any of the several plantations of sand pine I examined throughout the South. As plantation management of sand pine increases, and especially as thinning operations become more common, some losses to F. annosus can be expected. Studies on other southern pine species suggest that, within the region where sand pine is likely to be grown, F. annosus can be easily controlled by integrated practices such as summer thinning (16) and application of granular borax to the freshly cut surfaces of stumps.

SUMMARY

I have mentioned the few known diseases of sand pine likely to cause severe problems in managing plantations of sand pine through a pulpwood rotation. This species appears to be relatively disease-free in natural stands. As sand pine is planted more widely, farther from its native range, and under varying site and climatic conditions, and as it is maintained under different management practices, new disease problems will probably arise.

The most serious disease presently limiting the successful establishment of plantations of sand pine, particularly of the Ocala variety, is C. tabescens root rot. This disease may be severe in areas where hardwood stumps and root debris are left in the soil after site preparation. The pathogen readily colonizes the hardwood debris and attacks young sand pine at points of root contact. Losses to C. tabescens may be avoided by completely removing hardwood debris during site preparation; however, this removal may not be economical. Field observations suggest that the Ocala variety is more susceptible to C. tabescens than is the Choctawhatchee variety, but conclusive experimental evidence is still lacking to support this observation. If, from a silvicultural standpoint, it is desirable to plant seedlings of the Choctawhatchee variety instead of the Ocala variety, research to date on tree diseases has revealed no reasons to discourage such a program.

A confusing aspect of the problem of root rot in sand pine is the involvement of *P. cinnamomi*. Greenhouse studies suggest that both varieties of sand pine are highly susceptible to attack by this pathogen. Its association with areas where sand pine has declined and died in the field suggests that it may contribute to a root disease complex. A possible mode of action may be the destruction of the fine feeder roots, as occurs in littleleaf disease (3), and a resulting reduction in tree vigor and subsequent attack by *C. tabescens*. *P. cinnamomi* usually does not cause serious damage in well-drained, sandy soils; therefore, this pathogen is not expected to be a problem in such areas. Heavy clay or poorly drained soils may support populations of *P. cinnamomi*. Without exception, the areas in Florida and Georgia where planted sand pines had been killed by *C. tabescens* and where *P. cinnamomi* was later recovered were either shallowly underlain by clay soils or were composed of imperfectly drained sandy soils. Losses attributed to *P. cinnamomi* may be eliminated by avoiding such sites when planting.

LITERATURE CITED

1. Burns, R. M. 1968. Sand pine: a tree for west Florida's sandhills. J. For. 66: 561-562.

2. Campbell, W. A. 1949. A method of isolating *Phytophthora cinnamomi* directly from soil. U. S. Dep. Agric. Plant Dis. Rep. 33: 134-135.

3. __________ and Copeland, O. L. 1954. Littleleaf disease of shortleaf and loblolly pines. U. S. Dep. Agric. Circ. 940, 41 pp.

4. Hendrix, F. F., Jr., and Campbell, W. A. 1970. Distribution of *Phytophthora* and *Pythium* species in soils in the continental United States. Can. J. Bot. 48: 377-384.

5. __________ and Kuhlman, E. G. 1965. Factors affecting direct recovery of *Phytophthora cinnamomi* from soil. Phytopathology 55: 1183-1187.

6. Henry, B. W. 1953. A root rot of southern pine nursery seedlings and its control by soil fumigation. Phytopathology 43: 81-88.

7. Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. USDA For. Serv. Agric. Handb. 386, 658 pp.

8. Hodges, C. S. 1962. Black root rot of pine seedlings. Phytopathology 52: 210-219.

9. Hopper, B. E. 1958. Plant-parasitic nematodes in the soils of southern forest nurseries. U. S. Dep. Agric. Plant Dis. Rep. 42: 308-314.

10. Kuhlman, E. G. 1964. Survival and pathogenicity of *Phytophthora cinnamomi* in several western Oregon soils. For. Sci. 10: 151-158.

11. Powers, H. R., Jr., and Verrall, A. F. 1962. A closer look at *Fomes annosus*. For. Farmer 21(13): 8-9, 16-17.

12. Rhoads, A. S. 1956. The occurrence and destructiveness of Clitocy root rot of woody plants in Florida. Lloydia 19: 193-240.

13. Rishbeth, J. 1950. Observations on the biology of *Fomes annosus*, with particular reference to East Anglia pine plantations. I. The outbreaks of disease and ecological status of the fungus. Ann. Bot. 14: 365-383.

14. Ross, E. W. 1968. Sand pine, A new host of *Fomes annosus*. U. S. Dep. Agric. Plant. Dis. Rep. 52: 635.

15. ——————— 1970. Sand pine root rot--pathogen: *Clitocybe tabescens* J. For. 68: 156-158.

16. ——————— 1973. *Fomes annosus* in the southeastern United States: relation of environmental and biotic factors to stump colonization and losses in the residual stand. USDA For. Serv. Tech. Bull. 1459, 26 pp.

17. ——————— and Marx, D. H. 1972. Susceptibility of sand pine to *Phytophthora cinnamomi*. Phytopathology 62: 1197-1200.

18. Roth, L. F. 1963. *Phytophthora cinnamomi* root rot of Douglas-fir. Phytopathology 53: 1128-1131.

19. Rowan, S. J. 1960. The susceptibility of twenty-three tree species to black root rot. U. S. Dep. Agric. Plant Dis. Rep. 44: 646-647.

20. Ruehle, J. L. 1971. Reaction of two races of sand pine (*Pinus claus* to parasitism by the lance nematode, *Hoplolaimus galeatus*. (Abstr J. Nematol. 3: 328-329.

21. Smalley, G. W., and Scheer, R. L. 1963. Black root rot in Florida sandhills. U. S. Dep. Agric. Plant Dis. Rep. 47: 669-671.

FIRE AND SAND PINE

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Abstract.--Although many acres of Ocala sand pine in north-central Florida owe their existence to wildfires, the burning of standing trees is not an acceptable form of forest management. Most wildfires in this fuel type occur from February through June. Except during the spring, wildfires in stands of Ocala sand pine are easily controlled by plowed firelines, aerial tankers, suppression firing, and sand casters. Prescribed burning has not been effective in the management of sand pine except in the stands of the Choctawhatchee variety in west Florida.

Fire and Ocala sand pine (Pinus clausa var. clausa Ward) seem to go together. At least that seems to be the case on the Ocala National Forest in north-central Florida where the largest single concentration of this variety of sand pine is found. Many acres of sand pine forests in this part of Florida actually owe their very existence to fire. When a killing fire sweeps through a stand of cone-bearing trees, the serotinous cones open and release tremendous quantities of seed (1 million or more seed per acre).

If conditions are favorable, dense stands of reproduction usually follow. However, the standing trees are killed, and a potentially valuable resource is lost. This method of regeneration cannot be considered an acceptable form of forest management.

When young stands that have not reached seed-bearing age are destroyed by fire, the lack of an adequate seed supply precludes regeneration. In most instances, sand pine is replaced with scrub oak and other inferior scrubby species. These occurrences are known as "double burns"--they result when two or more burns take place within a time interval of about 10 years or less on the same piece of ground.

It is evident that fire and sand pine are not really as compatible as a cursory glance may indicate. We cannot afford to sacrifice wide-scale timber resources for the mere sake of producing a new generation of trees.

In comparison with the other southern pines, the Ocala variety of sand pine is very susceptible to fire kill. It usually grows in dense, even-aged, pure stands as a direct result of past fires. It is thin barked, attains an age of about 70 years old, and grows to a height of about 65 feet and a maximum diameter of 18 inches. The general stand characteristics lend themselves to easy and rapid fire spread under certain weather conditions. When a stand is composed principally of one species of tree, with all trees about the same age and size and with stems very close to one another, experience has shown that fires can spread from crown to crown with a minimum of surface or ground fuel. The fact that sand pine is a relatively small tree with very little in the way of protective bark makes it highly vulnerable to fire damage and kill.

Under most conditions, however, it is difficult to generate high-intensity fires in this timber type. When understory vegetation and ground cover are sparse, when fuel moistures and relative humidities are moderately high, and when strong wind movement is lacking, fires burn slowly and are easily subdued--often going out of their own accord. During the past 50 years, the Ocala forest has averaged less than two wildfires annually of 10 or more acres. Although several of these wildfires were of disastrous proportions, this infrequent occurrence over a long period illustrates the impracticability of generating many high-intensity fires. Past records also show that 80 percent of these wildfires occurred in the 5-month period from February through June. In the past 50 years, only 12 fires of any consequence occurred outside this seasonal period.

A rather complex combination of fuel and weather factors appears to be responsible for the occasional occurrence of blowup fires in sand pine stands during the spring. Hough (2) has identified some conditions that, when encountered in the right combination, help explain the reasons for large fires during the spring and may be of value to the land manager in formulating preparedness and manning schedules:

> "A complex combination of fuel and weather factors accounts for the dangerous fires that often develop during the spring in sand pine forests of Florida. Moisture content of live needles is lowest in March, and resin and energy contents reach their yearly highs during the 4-month period from February through May. These fuel properties become critical, however, only when they are accompanied by rainfall deficiencies that begin in the fall and winter and continue through the spring and by unstable air masses with low relative humidities and high winds."

Although Hough's findings were based on data from the Ocala variety of sand pine, there is evidence to indicate that the same fuel properties exist in other varieties. Preliminary tests show that understory vegetation also undergoes cycles in moisture, mineral, and extractive contents very similar to those in sand pine crowns.

FIRE CONTROL PROBLEMS

When fuel and weather conditions are ideal for burning, spring wildfires in dense stands of sand pine crown easily and are difficult to control. During many months of the year, however, conditions are less favorable for burning and stands of sand pine are not considered fire hazards. They are, in reality, often used as buffers or safety strips into which wildfires or prescribed fires are directed because of the inability of the fire to continue its spread through this type. Understory fuels are generally on the sparse side and, consequently, do not carry fire readily except under extreme weather conditions.

Disastrous wildfires in sand pine stands are few and far between. Under ordinary circumstances, plowed lines are effective in containing the small wildfire and it seldom reaches disastrous proportions. But when everything is right, small fires literally explode within a brief time span and the resulting conflagrations often defy normal control efforts. Under these conditions, early fire detection and prompt control are essential. Once the wildfire gains momentum, it fans up into the tree crowns where usual suppression measures are inadequate. Plowlines are not effective, and other ground attacks are equally futile.

Attacks with aerial tankers loaded with suppressants and retardants are showing the greatest promise of effective control of crown fires today. They are capable of knocking a fire out of the crown and bringing it back to the ground where it can be tackled by conventional tactics and equipment. Where large, contiguous areas of sand pine are encountered, aerial tankers armed with firefighting chemicals appear to be the best safeguard against a crown fire conflagration.

Suppression firing (i.e., the intentional application of fire to spee or strengthen control action on free-burning wildfires) may offer additional opportunities to break up or halt the advance of sand pine fires more effectively. Spot-fire patterns set well ahead of the wildfire head appear to be particularly suited for this type of treatment. The spots will consume mos of the understory fuel ahead of the fire spread. In addition, if they are permitted to develop moderate intensities of their own, they will consume som overstory fuel, thereby creating breaks in the crown canopy. In this manner, it becomes virtually impossible for the crowning wildfire to continue its forward advance. For the most part, it is relatively easy to predict the spread patterns of wildfires in sand pine stands because these patterns are basically wind-controlled.

The Michigan sand caster (1) was found to be a particularly effecti suppression weapon. In addition to building excellent lines to halt the advan of surface fires, the sand caster spread large quantities of soil and water i the overstory--enough so that crown fires were broken up and stopped.

PRESCRIPTION BURNING

Unfortunately, prescribed fire has not been a particularly effectiv tool in the management of sand pine. For the most part, failure to make effective use of fire in the form of a prescription is the result of our inabili to control intensities. Under some conditions, sand pine is an explosive fu type; under other conditions, it is an "asbestos forest." There seems to b little middle ground between these extremes. Interest in prescription burn stemmed from the species' past history of fire and regeneration. Natural seedfall from standing trees is sparse except when stands are exposed to k ing wildfires that open closed cones. When stands are harvested, the seed supply is left intact in the tops of trees. Lopping and scattering of the con bearing branches, followed by mechanical ground scarification, result in cone opening, seed release, exposure of mineral soil, and subsequent rege eration. But the costs are relatively high. The question arose as to wheth fire (a relatively cheap tool) might do the job just as well. To date, we ha not been able to make it succeed. If it sustains itself in slashings, it burn too hot and consumes most of the seed. Burns conducted for seedbed prep ration prior to harvesting have, on occasion, been successful, but they sti remain a gamble. The same situation prevails for hazard reduction burns An additional consideration: The most hazardous stands of sand pine are t less than 20 years old because such stands generally cannot withstand a go fuel-consuming burn without sustaining serious damage or kill.

There are, nevertheless, a few places where prescribed fire is applicable--mostly in west Florida. On the Eglin Air Force Base, burnin for hazard reduction is a common practice during the winter months. Und story fuels associated with sand pine are relatively light and produce low-intensity fires at this time of the year. In the more open stands, the fires often help to prune some of the lower limbs. During the drier times of the year, it is difficult to maintain low-intensity fires; excessive damage and kill are more likely to occur.

Except for these special cases, prescription burning is not currently recommended except possibly for purposes of slash disposal in clearcut areas which are to be regenerated artificially.

OTHER CONSIDERATIONS

For the most part, my remarks have been directed primarily toward Ocala sand pine found on the Ocala National Forest in north-central Florida--locally known as "The Big Scrub." In western Florida, the open-coned variety is known as Choctawhatchee sand pine. It frequently occurs in uneven-aged stands and often invades adjacent sites where fire protection is adequate.

The fire problem in natural stands of Choctawhatchee sand pine is not nearly as critical as it is in stands of the Ocala variety. The trees are more open-grown and are generally found in smaller, more accessible blocks. As a result, they are less likely to be involved in wildfire conflagrations. Nevertheless, a potentially dangerous fire situation may exist if either variety is used in extensive plantations. Because of its capacity to grow well on dry, infertile sites, sand pine is finding favor as a preferred species for planting in much of Florida. It is commonly used in converting scrub oak sites to pine. Sand pine plantations are characterized by dense, even-aged stands with long crowns. Under certain burning conditions, these characteristics make it relatively easy for surface fires to flare up into the crowns and spread rapidly through the plantation. Spread rates of 5 miles or more per hour are likely; control measures are difficult and often ineffective. Possible solutions may include wider spacings or pruning of the lower limbs when the stand is 10 to 20 years old.

If sand pine is to be managed as a productive natural resource, killing wildfires cannot be tolerated. As with so many other species with similar characteristics, this prohibition is easier to state than to follow. Once a large blaze is allowed to blow up, only a change in weather or a break in fuel continuity brings about complete control. The best manmade solution appears to lie with a more effective fire prevention program, improved detection, a quicker initial response to the wildfire, the use of aerial tankers, and the identification of critical fuel-weather situations for manning and preparedness purposes.

LITERATURE CITED

1. Crosby, John S., Johansen, Ragnar W., and Cooper, Robert W. 1963. The Model II Michigan Sand Caster. Cent. States For. Exp. Stn., U. S. For. Serv. Res. Pap. CS-2, 30 pp.

2. Hough, W. A. 1973. Fuel and weather influence wildfires in sand pine forests. Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-106, 11 pp.

ICE AND COLD DAMAGE TO SAND PINE--WEIGHING THE RISK

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Abstract.--The planting of sand pine north of its range increases the possibility of damage from cold and ice. The seriousness of this threat, the types of injuries sustained, and the likelihood of recovery are discussed. Consideration of tree and stand characteristics related to susceptibility suggests that proper management of sand pine stands to reduce the threat would emphasize proper spacing and no thinning.

This paper brings together information on the threat that ice storms and freezing temperatures pose to managed stands of sand pine. Sand pine management is in its infancy, and, where the species is most common, ice storms are few. Consequently, information is meager. Because sand pine is now being pushed northward, we must evaluate the potential hazards involved in the extension of the range of this species. For this paper, I have drawn upon written sources and unreported personal experiences of those who have worked with sand pine. Where experiences with other species appear relevant, they are included.

TYPES OF DAMAGE

The agent causing ice damage is most often termed "glaze" and is defined as a layer of ice formed by the freezing of rain on a surface whose temperature is at freezing or below. Whatever the term, we are concerned with storms that build up heavy layers of ice on stems and branches of trees.

The most common damage glaze causes to sand pine is mechanical and is due to the weight of ice building up on the surfaces of the trees. About 37 percent of the Ocala sand pines and 25 percent of Choctawhatchee sand pines in a 5-year-old plantation in South Carolina were damaged by a severe ice storm in 1969 (11). The weight of ice causing this type of damage has been estimated as being 15 to 20 or even 30 times the weight of the twigs or branches themselves (2, 3, 31). The most severe damage occurs when glaze storms are accompanied by wind. From experience with other species, we would expect eventually to encounter breakage of terminals and general stem breakage of sand pine, as well as uprooting on shallow soils (3, 8, 15, 27).

Physiological damage--killing of plant tissues by low temperature--is also possible. Harms (10) found symptoms indicating freezing as the primary cause of high mortality of Ocala sand pine introduced on sites near Columbus, Georgia, and Cheraw, South Carolina. Research in Florida has not revealed this effect, though freezing weather often occurs there. Two commercial planters in Florida have noticed no cold damage to sand pine over the last 5 years (Don Blizzard and George Eubank, personal communications, 1972). Poor planting technique is considered a greater hazard. Noah Corbin (personal communication, 1971) reports that the only damage occurring to sand pine at Eglin Air Force Base during the past 35 years has been the freezing of some baled seedlings when ambient temperatures fell below 20° F. (-7° C.). Glaze was not a factor in these reports. Sand pine on the Ocala National Forest has been subjected to ice: "... in 1957 almost all the Big Scrub was iced over," but damage was negligible (Spurgeon McDuffie, personal communication, 1972).

W. E. Howell (personal communication, 1972) reports that a small stand of Ocala sand pine on the Atomic Energy Commission's Savannah River Project in South Carolina came through a severe ice storm that decimated slash pine. Many green needles were knocked off the sand pine, but the trees are healthy now.

In growing pines in southern nurseries, freezing can be troublesome if care is not taken. Wakeley (33) reported that newly germinated seeds of the southern pines can suffer freezing damage, but he felt such damage could be overcome by not planting when germination would occur during a hazardous period. There are reports (Wilbert E. Schowalter, personal communication, 1971) that grafted sand pines in the Ashe Nursery in Mississippi have been damaged by cold weather. There is some possibility, however, that other factors were responsible.

Once pines have been injured by low temperatures or ice, the injured stems can suffer further damage from exposure to infection by fungi and invasion by insects. Fortunately, such damage seems to occur with far less frequency than would be expected (24, 29). Russell (29) reports that a storm broke virtually every stem (most within the crown) of a 25-acre loblolly pine stand in northern Louisiana. Although the stand was not treated in any way for a year, there was no reported damage from insects and disease. In a survey of damage from the Louisiana ice storms of 1944 and 1947 in loblolly, longleaf, shortleaf and slash pines, Muntz (24) found no serious damage from insect attack. Cool et al. (6) found a buildup of insects in injured timber, but these insects did not spread to healthy trees.

Nevertheless, we should watch for possible insect attack after severe weather. Kirby (16) attributed the epidemic of the southern pine beetle in southwestern Mississippi in 1952 to the ice storm of January 1951. In his opinion, the buildup was aided by the storm's injury to birds that were insect predators.

MAGNITUDE OF THE RISK

Likelihood of ice damage is related to the regional frequency of storms. As might be expected, the greatest incidence of storms occurs in the northern United States, particularly in the eastern half of the country (3, 6).

Figure 1 shows a section of the southeastern United States with the sandhills outlined and zones of ice-storm frequency demarcated. The occurrence of glaze storms over the 27-year period from 1925 to 1953 is indicated in each zone. Four zones are apparent in the region. The lack of ice storms south of central Georgia during the 27-year period does not entirely exclude the possibility of such storms there in the future (19). According to Lemon's information (19), the occurrence of glaze was moderate in the zone that crosses central Georgia, and Cool et al. (6) list the maximum number of storms in this area during the 27-year period as two. After studying weather records for this area from 1893 onward, Jones (14) concluded that damaging ice storms occurred there once every 12 years. This zone covers the eastern sandhills in Georgia and then follows the coastal plain in the Carolinas. Because the sandhills in the latter states are in a zone where as many as six glaze storms occurred during the period, the risk of future storms there is three times as great as in the zones nearer the coast. Still greater occurrence (13 storms) was recorded in the next zone inland. Although this zone may appear too far inland to be of concern to us, it does border the Carolina sandhills.

Frequency does not tell the whole story. In 1947, Muntz (24) cited reports which indicated that in a particular area, an ice storm of great severity had not occurred in 40 years. He went on to say (24, p. 142), "... yet, two have occurred within [a period of] 4 years." Obviously, a recent storm does not diminish the risk of a second occurrence in the near future. Generally, though, the risk can be linked with the frequency of storms in the past, and cold and ice storms will be greater hazards to growing sand pine as it is planted farther north, where storm severity and frequency are likely to be greater.

CONDITIONS AFFECTING DAMAGE

Apart from severity of the storm, the conditions that affect the amount of damage done are species (as embodying differing morphology and physiology), size, and age of the trees. Characteristics of the stand that are important are stand density and distribution and whether the stand is natural or planted.

Species

Ice damage has been found to occur to all of the southern pines. Relative susceptibility is uncertain because of differences in "...age, size, density, or location...." (24, p. 143). This may be the cause of the variable and contradictory replies that Cool et al. (6) received to their questionnaire on the susceptibility of individual species. On plots where conditions were under stricter control and data were more methodically obtained, slash pine was found to be the most susceptible species.

Hebb (11) reported that, after a storm in South Carolina, Choctawhatchee sand pine was about equal to slash pine in susceptibility. Actually, the performance of Choctawhatchee sand pine could be judged superior because the two species sustained equal damage even though the sand pines were taller and had a lower stand density than the slash pines. (Tree height and density of stocking are both factors that affect the degree of ice damage and will be discussed later in this paper.) About 25 percent of the trees in the stands of Choctawhatchee sand pine, slash pine, and longleaf pine were damaged. Ocala sand pine fared much worse, with 37 percent damage, and loblolly pine was the least affected, with 13 percent.

The effect of glaze is not only a function of the quantity of ice, but is also related to the strength of the wood, the arrangement of the branches (19) and probably their number, and to the length of the needles. Trees of similar anatomy should behave similarly. Gross morphology is important because the ice forms on surfaces. McKellar (21, p. 797) attributes the greater susceptibility of slash and longleaf pines over that of loblolly pine to "...their denser and more persistant foliage, which accumulates a greater ice load." And, according to Lemon (19, p. 24), "Medium-sized branches... have more strength in proportion to surface area than extremely large or extremely small branches." Lemon (19, p. 24) believes that a "... strong central trunk with small flexible side branches might be resistant."

Though we have no great store of data for sand pine, we might expect that it would behave somewhat like shortleaf or even loblolly pine because all three have similar, short needles. This similarity is encouraging because loblolly and shortleaf pines are comparatively resistant to ice damage. Virginia pine, a northern species morphologically similar and genetically related to sand pine (20, 22), readily recovers from bending by heavy blankets of snow (9). The short branches and stem flexibility of plantation-grown sand pine should give it a similar advantage (28).

Overriding these apparent affinities are differences even among varieties. Though gross anatomical differences are evident, the two varieties of sand pine also differ physiologically. The Ocala variety breaks dormancy before the Choctawhatchee variety and, indeed, may grow continuously, exposing the tree to damage from sudden cold spells. Żelawski and Strickland (34) report, that under controlled conditions, the Ocala variety broke dormancy more readily than the Choctawhatchee variety. It is not surprising that damage in the Carolina plantings was greatest to the Ocala variety (11). Although Harms (10) acknowledges the necessity for further test plantings, he believes Ocala sand pine's susceptibility to cold would probably rule it out as a planting choice for the Georgia-Carolina sandhills. If variation of sand pine demonstrated by Morris (23) can be utilized, it may be possible to develop genetic resistance to freezing and ice damage from within the species.

Intraspecific variations relating to ice damage in other species were reported by Jones and Wells (15). When planted in central Georgia, loblolly pines from colder, inland seed sources were harmed less by ice storms than those from areas with a more moderate climate.

Size

The average size of the trees in the stand also affects the severity of the damage. It is difficult to generalize, but stocky trees appear better able to resist bending and breakage, and very slender trees tend to bend with the weight of ice and then usually recover. However, stems between these two extremes are not supple enough to resist breakage; consequently, they usually break or are uprooted.

It may be a mistake to try to link damage to a definite size--except in a very general way. The relationship will vary with the weight of the ice, the wind velocity, and the proportions of the stems. Moreover, glaze occurrence itself is rather spotty (6). Pole-sized trees appear to be most easily damaged, but there have also been reports of severe storms damaging trees the size of small saw logs (6). Young pulpwood-sized trees with good crowns and stocky stems appear able to withstand glaze storms best: Downs (8, p. 2 notes that "...damage is light and consists mainly of slight bending and a litt top breakage" and that "...the most prevalent type of damage for trees 6-10 inches d.b.h. is bole and top breakage, with uprooting heavy at times." Tall spindly trees with sparse crowns--the type of trees developed under crowded conditions and dense overstories--usually are greatly damaged (6, 8, 25).

Because the trees observed by Hebb (11) after the Carolina storm were only 5 years old, the legitimate inferences that can be drawn from the data are limited to the varying responses of the different species on the study plots. The effects of storms on older, larger sand pine at that latitude may be different. Certainly, damage reached catastrophic proportions in neighboring plantations of pole-sized slash pine.

Age

Older trees affected by glaze tend to break rather than bend, but it is difficult to document any precise relation to age. Most observers responding to the questionnaire sent out by Cool et al. (6) agreed that trees less than 6 to 10 years old usually bent under the load of ice. Breakage was more common in older trees. Daley (7) felt that stands older than 12 to 15 years were damaged most. These observations may indicate that the degree of damage changes with the stages in the development of the trees (30), but this problem has not yet been formally studied.

Stand Density

In the survey initiated by Cool et al. (6), nine respondents believed glaze damage was greater in dense stands and seven thought it was less. In addition to stand density, other factors are involved; as these factors vary, the results that appear to be due to density also vary. Merely relating ice damage to density is an oversimplification.

Some observers believe that a heavily stocked forest is a safeguard against ice damage because the trees provide mutual support and that isolate trees are more prone to breakage (8, 12, 19). Slocum and Miller (32) felt this relationship was true of Virginia pine, which resembles sand pine. Downs (8) on the other hand, felt that, in such stands, breakage could be severe because the spindly nature of the trees would place them at a disadvantage. Muntz's (24) data show ice damage of slash pine to be greater in dense stands. Muntz points out that this relationship is of no practical importance because greater numbers of undamaged trees will remain in the dense stands after the storm. Abel (1) observed higher damage in heavily stocked stands and attributed it to the damage wrought on adjacent trees by weaker ice-loade trees as they bent. Respondents to the questionnaire of Cool et al. (6) felt that open-grown trees were resistant, and others (8) have seen greater taper and more robustness in open-grown trees, hence, a greater ability to withstand the onslaught of ice and wind. Thus, there is much confusion as to the effect of stand density. Although isolated trees are more exposed and fully stocked stands are more protected, the very protection of the fully stocked stands fosters the growth of tall and spindly trees susceptible to bending and breaking.

A major source of trouble can be the sudden reduction of density resulting from thinning or opening up the stand, as in clearing or preparing rights of way. In plantations of loblolly pine that were being thinned experimentally, Brender and Romancier (5) found severe destruction after a glaze storm. Damage was markedly less in plots that were not thinned. Daley (7) noted that recreational areas were hard hit by ice storms, possibly because such areas are customarily left open.

Some observers believe that unbalanced crowns may be a cause of much of the bending that occurs in glaze storms (13). This imbalance is thought to be the reason that trees bordering roads and other openings are so apt to bend: the side of the crown toward the opening is generally more heavily developed. This theory is not fully accepted. In Louisiana, Kuprionis (17) observed that a number of slash and loblolly pines with one-sided crowns were not bent more readily than neighboring trees with symmetrical crowns. Perhaps more damage is noticed at road edges because the damage is most readily seen there.

REDUCING THE RISK

How can we lessen the threat of ice damage without taking sand pine out of the scene entirely? It appears to be the best species for reforestation of deep sands. High-risk regions can be avoided, but any location will pose some threat. Moreover, the problem cannot be solved merely by deciding not to move northward, for there are variables within location. To decide with assurance, we will probably have to wait until we know more about the performance of sand pine in different areas. The work unit of the Southeastern Forest Experiment Station at Marianna, Florida, is presently installing more studies of sand pine north of its original range. Such studies will give us more knowledge of survival and growth and of disease and insect hazards, and this knowledge will enable us to make more reliable decisions.

Management can help reduce the risk by manipulating the density with restraint. Altering density in a drastic way can make the remaining stands very susceptible. Thus, thinning, harvesting, clearing--any cutting that leaves part of the stand exposed--will make it more susceptible, as demonstrated for loblolly pine by Brender and Romancier (5), for slash pine by Daley (7), and for Virginia pine by Slocum and Miller (32). However, thinning practices can be used that will leave a strong stand: thinning from below by taking out the smaller trees, and thinning only lightly, as advocated by Muntz (24) for longleaf pine, to avoid glaze damage.

Thinning in dense stands of tall, slender trees should be avoided if possible (8). Respondents to the questionnaire of Cool et al. (6) thought that maximum damage occurred in recently thinned stands of close-grown trees. Thus, if thinning is to be carried out, it must be done early in the life of the stand in order to allow the development of a stand of vigorous residuals. If it is delayed until only slender trees can be left, thinning should not be attempted at all.

AFTER THE STORM

If a storm does hit, what should we do? First of all, we should not simply rush in and start to work. It is best to wait before actually assessing the damage, because the first impression is usually false, and many damaged trees recover. Damage is often far less than is feared. Although the buildup of insect populations and the danger from fire must be guarded against, panic leading to overcutting should be avoided (18). Planning is an important factor in minimizing losses that result from glaze (6).

There is no harm in letting the stand alone for a while. Little additional damage has been found to occur, and there is little deterioration. Except for breakage of the lower bole and uprooting, there seems to be little evidence of death resulting directly from ice damage. This was the conclusion of Jones and Wells (15) after studying a stand of loblolly pine in Georgia. Kuprionis (17) attributed the death of slash pine in northern Louisiana to a snow storm, but the deaths took place in the second year after the storm and the trees were bent over and never recovered.

Pines can recover from many of the principal types of damage we are concerned with. Uprooted trees are generally too far gone and too much in the way to be saved, but bent-over trees often recover, and broken trees, if they still bear some limbs, survive and may even grow. Muntz (24) observed that small trees recover better than taller trees. McKellar (21), while studying loblolly, longleaf, and slash pines, observed that 90 percent of the slightly bent trees recovered completely, as did 40 to 56 percent of the badly bent trees. An additional 20 to 30 percent made partial recovery. In Mississippi, Roberts and Clapp (26) found that pruning aided recovery of bent slash pine.

Permanent bending, or "set" as it is called, is common after ice damage to hardwoods of the northeastern United States (19). Hough (12) describes its occurrence in black cherry and the sprouting that subsequently took place all along the stems. Russell (29) feels that the usual pattern in the

South is for recovery to be rather common and for severe damage and breakage to occur only in patches. Kuprionis (17) reports that glaze-damaged loblolly and shortleaf pines recovered 18 years after damage: of 125 trees from four plots, 35 percent were straight, 49 percent were slightly crooked, and only 16 percent were permanently crooked.

What we ultimately do about glaze damage will depend on the goals of our management. If we are managing for special products and not simply for pulpwood, we probably have thinning schedules and can salvage damaged trees in the course of thinning. In Louisiana, Russell (29) used such a tactic to restore a stand of loblolly pine in which every stem was broken and up to half of each crown was lost. He postponed any cutting for a year and then applied successive thinnings to clean up the stand.

If the management scheme does not include thinning, as it probably will not in growing sand pine for pulpwood, damaged trees can possibly be left until the final harvest. Slightly bent trees should be no problem for pulpwood. Muntz (24) observed that leaning trees continued to produce volume. Cool et al. (6) reported that broken trees with only a few branches were still alive a year after the storm.

Salvage of down timber is a harvesting problem. Once there is a large quantity of such wood that will not grow and will not keep, the problem is to get it out before it loses weight or deteriorates. Cool et al. (6) noted complaints of weight loss as early as 2 months after the storm, but most complaints came 4 months later. Deterioration was noticeable in 4 months, but most was noticed 6 months after the storm. Topwood completely broken from the stem became a problem somewhat earlier. This is a problem that can be solved by planning. Hasty action is not called for, but time and resources must be carefully utilized.

CONCLUSION

As sand pine is extended to more northern sites, we can apparently expect an increase in the frequency of exposure to glaze. Damage from low temperature itself seems remote if the Ocala variety is avoided; the principal threat is mechanical damage from heavy deposits of ice. The threat to sand pine should be no greater than that to slash pine. In establishing stands of sand pine, crowding should be guarded against, for it makes the stands susceptible to ice damage. When pulpwood is the final product, management should emphasize proper spacing, with a goal of 75 square feet per tree, and no thinning.

LITERATURE CITED

1. Abel, G. W. 1949. Ice damage heavy in slash pine planting. For. Farmer 8(5): 11.

2. Abell, Charles. 1934. Influence of glaze storms upon hardwood forests in the southern Appalachians. J. For. 32: 35-37.

3. Baxter, Dow Vawter. 1943. Pathology in forest practice. 618 pp. New York: John Wiley.

4. Bennett, Iven. 1959. Glaze--its meteorology and climatology, geographic distribution and economic effects. U. S. Army Quartermaster Res. & Eng. Cent., Environ. Prot. Res. Div. Tech. Rep. EP 105, 217 pp.

5. Brender, E. V., and Romancier, R. M. 1960. Glaze damage in loblolly pine plantations. South. Lumberman 201(2513): 168.

6. Cool, B. M., Goebel, N. B., Wooten, T. E., and Loadholt, C. B. 1971. Glaze damage to pine trees in the Sandhills area of South Carolina. Clemson Univ. Coll. For. & Recreation Resour., Dep. For., For. Res. Ser. 21, 12 pp.

7. Daley, R. M. 1964. How much ice damage? After a severe winter, the South takes stock. For. Farmer 23(9): 10-11.

8. Downs, A. A. 1943. Minimizing glaze damage in pine. USDA For. Serv. Appalachian For. Exp. Stn. Tech. Note 55, 5 pp.

9. Fenton, Richard H. 1959. Heavy snowfalls damage Virginia pine. USDA For. Serv. Northeast. For. Exp. Stn. Pap. 127, 7 pp.

10. Harms, William R. 1969. Sand pine in the Georgia-Carolina sandhills: third-year performance. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-123, 3 pp.

11. Hebb, E. A. 1971. Resistance to ice damage—a consideration in reforestation. USDA For. Serv. Tree Plant. Notes 22(2): 24-25.

12. Hough, A. F. 1959. Zoning for the management of black cherry on the Allegheny Plateau. J. For. 57: 353-357.

13. Illick, J. S. 1916. A destructive snow and ice storm. For. Leaves 15(7): 103-107.

14. Jones, Earle P., Jr. 1969. Growth comparison. Slash and loblolly pine in Georgia. For. Farmer 28(5): 10-12.

15. __________ and Wells, Osborn O. 1969. Ice damage in a Georgia planting of loblolly pine from different seed sources. Southeast. For. Exp. Stn., USDA For. Serv. Res. Note SE-126, 4 pp.

16. Kirby, John. 1954. Death strikes the woods. For. Farmer 13(6): 5, 10-11.

17. Kuprionis, John. 1970. Recovery of loblolly, slash, and shortleaf pines bent by snowfall and/or ice. La. Polytech. Inst. Bull. 4, 35 pp.

18. Kyle, George. 1960. Report on March ice damage to timber. For. Farmer 19(10): 6-7.

19. Lemon, P. C. 1961. Forest ecology of ice storms. Torrey Bot. Club Bull. 88(1): 21-29.

20. Little, Elbert L., Jr., and Righter, Francis I. 1965. Botanical descriptions of forty artificial pine hybrids. USDA For. Serv. Tech. Bull. 1345, 47 pp.

21. McKellar, A. D. 1942. Ice damage to slash pine, longleaf pine, and loblolly pine plantations in the Piedmont section of Georgia. J. For. 40: 794-797.

22. Mirov, N. T. 1967. The genus Pinus. 602 pp. New York: The Ronald Press Co.

23. Morris, John E. 1967. Racial variation in sand pine seedlings. Ninth South. Conf. For. Tree Improv. Proc. 1967: 132-136.

24. Muntz, H. H. 1947. Ice damage to pine plantations. South. Lumberman 175(2201): 142-145.

25. Nelson, T. C. 1951. Ice damage high for spindley residual saplings. For. Farmer 10(12): 6.

26. Roberts, E. G., and Clapp, R. T. 1949. Pines severely damaged by ice recover after pruning. Miss. Farm Res. 12(5): 1, 5.

27. __________ and Clapp, R. T. 1956. Effect of pruning on the recovery of ice bent slash pines. J. For. 54: 596-597.

28. Rogers, W. E. 1923. Resistance of trees to ice storm injury. Torreya 23(6): 95-99.

29. Russell, E. J. 1967. Ice damaged timber management. La. Polytech. Inst. Bull. 1, 9 pp.

30. Schaffalitzky de Muckadell, M. 1954. Juvenile stages in woody plants. Physiol. Plant. 7: 782-796.

31. Schrenk, Hermann von. 1900. A severe sleet-storm. Acad. Sci. St. Louis Trans. 10: 143-150, plates X-XI.

32. Slocum, G. K., and Miller, W. D. 1953. Virginia pine: reproduction, growth and management on the Hill Demonstration Forest, Durham County, N. C. N. C. Agric. Exp. Stn. Tech. Bull. 100, 52 pp.

33. Wakeley, Philip C. 1954. Planting the southern pines. USDA For. Serv. Agric. Monogr. 18, 233 pp.

34. Żelawski, W., and Strickland, R. K. 1973. Temperature effects on growth, assimilation, and bud development of sand pine. In Sand pine symposium proceedings 1972. USDA For. Serv. Southeast. For. Exp. Stn.

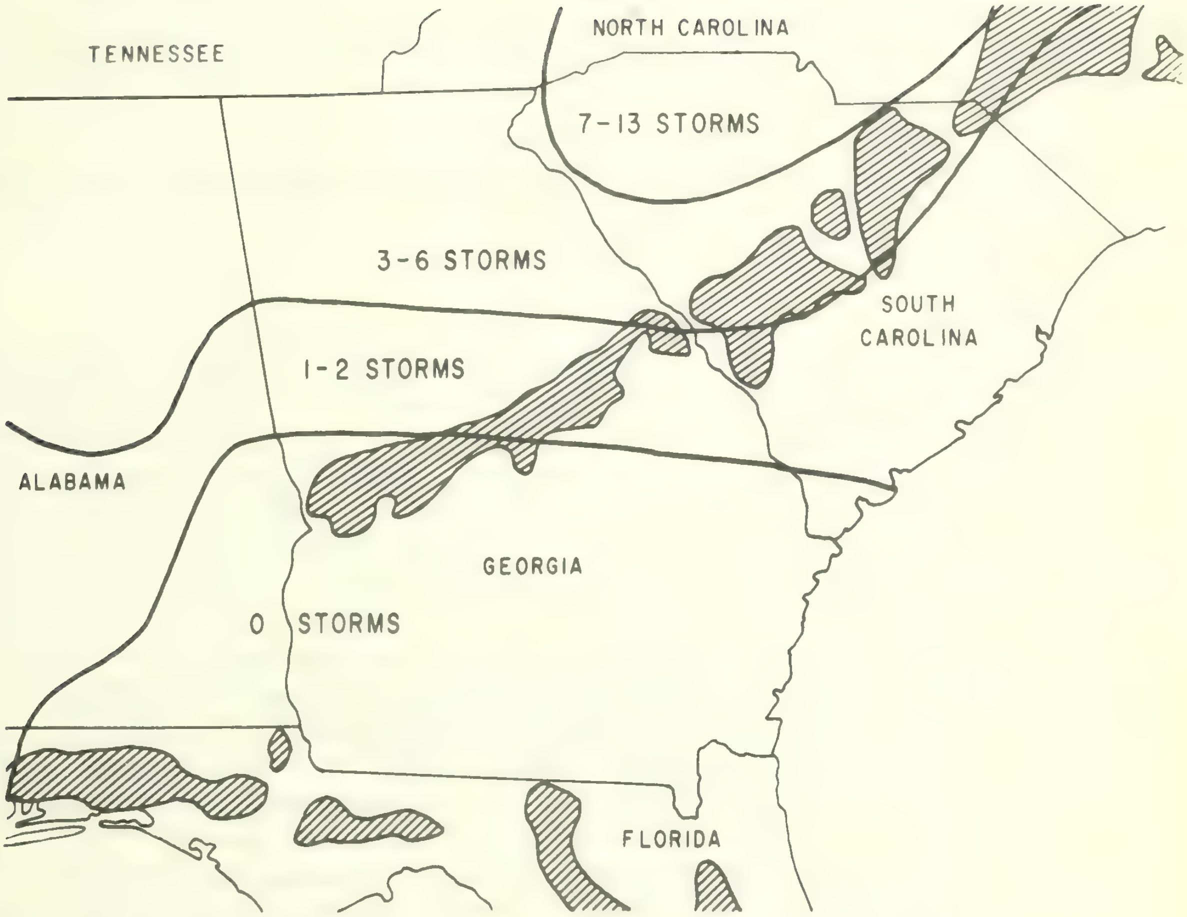

Figure 1.--Zones of ice-storm frequency in the southeastern United States for the period 1925 to 1953. The sandhills are indicated as crosshatched areas. [Map adapted from Bennett (4).]

GENETICS OF SAND PINE AND THE PROGRAM FOR SUPERIOR TREE SELECTIO

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Abstract.--Choctawhatchee sand pine has better tree form and a higher survival rate than does Ocala sand pine, but the latter is superior in first-year growth and weight increase. The two varieties also differ in cone and seed traits, wood specific gravity, and susceptibility to mushroom root rot. Variation among stands is much greater than within-stand variation. Numerous selections of both varieties are now available for tree improvement programs, and improvements are anticipated in average straightness, natural pruning, and growth.

Among the southern pines, sand pine is uniquely adapted to growth on the deep, infertile sandhill soils in Florida. Sand pine naturally occurs on approximately one-half million acres (4). On a substantial portion of

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more than 2 million additional acres of sandhill land in the State, sand pine is the forest tree species capable of best economic growth (1). Sand pines produce usable wood, but the tree form is not one that brings delight to the logger's eye. Stands contain many crooked, limby, medium- to small-sized stems. However, because of projected wood requirements and the need to increase the productivity of the sandhills, there has been a great increase in interest in planting sand pine since 1960. This interest, in turn, brought pressure for the genetic improvement of planting stock of sand pine.

The present paper is concerned with studies of natural variation in tree characteristics of this species and with cooperative efforts to develop improved seed sources.

VARIATION IN TREE CHARACTERISTICS

Data Acquisition

In 1965, personnel from the USDA Forest Service Research Center at Marianna, Florida, the Florida Forest Service, St. Regis Paper Company, and the University of Florida coordinated the search for outstanding sand pine trees and the collection of data to provide a basis of comparison of the trees selected. Superior phenotypes of sand pine were first selected in natural stands on Eglin Air Force Base in west Florida. With approximately 25 excellent trees located, a series of measurements were made of selected trees and of 10 nearby dominant trees of the same species at the site of each selection.

Selections were also made by the same group on the Ocala National Forest and other sand pine stands in that area. In addition, permission was granted for use of a number of selections made independently on the Ocala National Forest by personnel of Region 8, National Forest Administration.

In the stands of each variety--Choctawhatchee and Ocala--of sand pine, measurements of each selected and check tree were made as follows:

1. D.b.h.
2. Total height
3. Lean--the horizontal distance between the bole center at the base and at the top (omitted in stands of the Choctawhatchee variety)
4. Crook--number of deviations from a straight line in the merchantable bole

5. Maximum deviation of the bole--the distance of the bole center at the largest crook from a straight line drawn between bole centers above and below the crook

6. Branch-free length--measured from the base to the lowest living or dead branch or branch stub

7. Limbiness--number of branches between 20 and 30 feet above the base

8. Branch diameter--an estimate of the average diameter of the limbs in major whorls in the lower one-third of the crown (omitted in stands of the Choctawhatchee variety)

9. Branch angle--an estimate of the average angle from the vertical to the branches in major whorls

10. Crown diameter--measured across the widest and narrowest portions of the crown

11. Length of live crown

12. Number of annual rings at breast height

13. Bark thickness at breast height.

Specific crew members were assigned the various measurements or estimates in order to obtain a degree of consistency in values recorded. On the basis of measurements made, certain other characteristics were calculated:

14. Merchantable volume in cubic feet

15. Surface area of conical crowns

16. Crook index--number of deviations per tree multiplied by maximum deviation.

Among the Choctawhatchee variety, 15 stands containing 150 check trees were measured. Similar observations were made on 21 stands and 205 check trees of the Ocala variety.

RESULTS AND DISCUSSION

Data from the two populations were analyzed separately to determine, for each measured and calculated characteristic, the variance among and within stands. Means of the selected and check trees were calculated, and the pooled mean standard deviations within stands of each population were used as a measure of the selection differential (table 1). The means of the check trees were assumed to be representative of the dominant tree populations.

The different variances of the several traits in the two populations reflect, to a large extent, the different stand conditions. The Ocala variety typically grows in dense, even-aged stands in contrast to the less crowded, more uneven-aged stands of the variety in west Florida. Thus, selections of the Ocala variety tended to have somewhat larger crowns than did the crowded, smaller trees surrounding them. In contrast, selections of the Choctawhatchee variety could be found with more volume and more compact crowns than their relatively open-grown checks.

The combined selection for compact crowns and large boles could have a compound effect on volume production per unit area. On the assumption that crown spread indicates the area required per tree, a fully stocked stand with crowns the size of the selections of the Choctawhatchee variety would contain 376 trees per acre as opposed to the 221 check trees. If these 376 trees had the same volume per tree as the selections, there would be an increase of 90 percent in volume per acre over a rotation. Although not so striking, similar calculations for the selections of the Ocala variety indicate a 34-percent increase in volume per acre. Even with low heritability of these traits, substantial increases in production per acre can be anticipated through use of selected sand pine progenies.

The data reported here also agree with the general observations that the form of Choctawhatchee sand pine trees is better than that of Ocala sand pine trees. In all measurements of bole crookedness, the check trees of the Ocala variety scored worse than the Choctawhatchee sand pine population, although it was possible to locate selections in both varieties with very acceptable straightness. Furthermore, many trees in the stands of the Ocala variety have a pronounced lean. This tendency is lacking in the population of the Choctawhatchee variety and was not measured. The west Florida trees tend to be slightly more limby, partially because of their lower stand density, and to have a sharper branching habit.

In addition to distinct differences between the two main populations, analysis of variance indicated highly significant differences among stands in both populations for all traits except branch angle. In other words, if we exclude the selected trees, variation among stands was much greater than within-stand variation. As there were substantial differences in age and

Table 1. --Means and variations of the characteristics of selected and average sand pine trees of two varieties

Trait	Ocala variety				Choctawhatchee variety			
	Selected trees	Check trees	Standard deviation	Selection differential[a]	Selected trees	Check trees	Standard deviation	Selection differential[a]
D. b. h. (in.)	10.5	9.6	1.46	0.61	10.3	10.1	0.91	0.21
Height (ft.)	70.4	65.1	5.31	1.00	63.9	58.2	3.65	1.57
Bark thickness (in.)	.83	.83	.17	.01	.4	.43	.10	.12
Volume (cu. ft.)	23.5	17.0	7.66	.85	19.2	17.0	3.78	.57
Lean (ft.)	1.3	3.4	2.6	.80	---	---	---	---
Crooks (No.)	.8	3.2	1.5	1.58	1.6	2.4	1.3	.66
Maximum crook (in.)	2.9	12.0	7.6	1.19	1.7	3.7	2.2	.89
Crook index	2.4	41.9	40.7	.97	3.8	11.0	10.9	.67
Branch-free length (ft.)	9.8	6.3	4.3	.81	7.8	4.0	2.1	1.81
Limbiness (No.)	13.9	14.9	4.2	.23	15.5	19.0	3.5	.99
Branch diameter (in.)	1.8	1.8	.5	.07	---	---	---	---
Branch angle (degrees)	65.4	65.3	8.6	.02	47.8	47.3	8.7	.06
Crown radius (ft.)	7.6	7.5	1.6	- .02	7.1	8.9	1.5	1.19
Crown length (ft.)	27.7	26.2	6.3	- .25	24.8	26.1	4.6	.27
Crown surface area (sq. ft.)	744	680	262	- .25	588	799	237	.89
Age (yr.)	34.4	35.5	2.3	.44	36.9	36.0	2.0	- .42

[a] Difference between selected and check trees divided by the standard deviation.

stand density of the various stands, large differences in average size could be anticipated. Such differences in crook measurements are not as easily explained. Similarly large stand differences in the specific gravity of sand pine were previously observed by the authors. Such distinct stand differences suggest that interbreeding populations of sand pine are quite small in number of individuals and in area, even in the large, continuous total population that occurs on the Ocala National Forest. Such distinct stand differences over relatively short distances are not frequently observed in other southern pine species.

SURVIVAL, GROWTH, AND OTHER TRAITS

In a study of morphological and physiological traits of sand pine under greenhouse conditions, Morris (6) found significant differences among seed sources in response to plant nutrients and a general superiority in first-year growth of the Ocala variety. Similarly, Żelawski and Strickland (8) reported a more rapid weight increase for the Ocala variety. However, both reports mentioned that seedlings of the Ocala variety had a lower survival rate than did those of the Choctawhatchee variety, under experimental conditions and in operational field plantings.

In order to gain further data on the relative survival and growth of seedlings of the two varieties under field conditions, a series of test plantings was established in 1970. In addition to seedlings from representative seed collections from Eglin Field and the Ocala National Forest, a third seed source from the Withlacoochee River State Forest was used. Test plantings were established on typical sites of deep sand in several east and west Florida locations. Overall planting success was varied and depended upon local weather and site conditions, but superior survival of the Choctawhatchee variety was evident at all locations (table 2). Growth of the surviving trees of the Ocala variety was good, but wood production per acre will be reduced by poor survival.

Worthy of note is the performance of seedlings from the Withlacoochee source. Morris (6) found that, although trees from this area have many similarities to those of the main population of the Ocala variety, they have several distinctly different traits.

Several other characteristic differences between the sand pine varieties have been reported, including cone and seed traits, wood specific gravity, and susceptibility to mushroom root rot caused by Clitocybe tabescens (table 3). Also, ovulate strobili of Ocala sand pines are receptive in late December or early January, whereas peak receptivity for the Choctawhatchee variety is usually 2 or 3 weeks later. Thus, the two varieties have numerous differences of economic or biological importance, and these differences have direct bearing on decisions concerning their genetic improvement.

Table 2.--Early survival of sand pine seedlings from three seed sources

Seed source	Location and planter					
	Volusia County, Florida Forest Service	Volusia County, Union-Camp Corp.	Alachua County, Univ. of Florida	Calhoun County, USDA Forest Service	Walton County, U.S. Air Force[a]	Bay County, St. Joe Paper Co.[b]
	Percent survival					
Choctawhatchee	88	49	37	94	90	87
Ocala	60	36	20	68	78	60
Withlacoochee	57	50	14	82	85	75

[a] In the Walton County planting, mean 2-year heights (in feet) were 2.6 for Choctawhatchee, 2.8 for Ocala, and 2.5 for Withlacoochee.

[b] In the Bay County planting, mean 3-year heights (in feet) were 3.4 for Choctawhatchee, 3.8 for Ocala, and 3.7 for Withlacoochee.

Table 3.--Contrasting characteristics of Ocala and Choctawhatchee sand pines

Characteristic	Ocala	Choctawhatchee	Reference
Cone opening	Serotinous	Nonserotinous	Little and Dorman (5)
Seed size	89,800 seed/kg.	109,200 seed/kg.	Morris (6)
	104,000 seed/kg.	123,700 seed/kg.	Barnett and McLemore (2)
Seed color	Dark	Light	Morris (6) Barnett and McLemore (2)
Wood specific gravity	0.439	0.485	Clark and Taras (3)
Susceptibility to root rot	Susceptible	Resistant	Ross (7)

IMPROVEMENT PROGRAMS FOR SAND PINE

A number of excellent phenotypes of both Ocala and Withlacoochee sand pines were added to the original selections, and early selections that scored poorly were deleted. Selections now available, including new ones made in west Florida in 1970 and 1971, for use in the program for the improvement of sand pine include the following:

Variety and location	Selections (No.)
Ocala	
Ocala National Forest	63
Withlacoochee State Forest	11
Outlying stands in Volusia and Clay Counties	12
Choctawhatchee	
Eglin Air Force Base and vicinity	76
Franklin County stands	17

Clonal orchards for both varieties were established by the Florida Division of Forestry and St. Regis Paper Company. These orchards are now producing some cones. Although no data are available on inheritance of important traits in sand pine, we expect, on the basis of results with other southern pine species, that progenies of these orchards will be appreciably better than common planting stock.

In other pines, traits related to stem quality are highly heritable. Because of the selection differentials for sand pine (table 1), we anticipate appreciable improvement in average straightness of orchard progenies along with some increase in natural pruning tendencies. Furthermore, as discuss earlier, growth should be better than with unimproved stock.

Recently, several companies have initiated establishment of sand pi orchards. Because of the problem with initial planting survival of the Ocala variety and its susceptibility to mushroom root rot, improvement efforts are being concentrated on the Choctawhatchee variety. Both clonal and seedling orchards have been started or are being planned.

Clonal orchards employ established methods of grafting and are similar in design to those of other species. Because of the ability of sand pines to produce cones at a very early age, the species is well adapted to the establishment of seedling orchards and to a rapid turnover of breeding generations. Open-pollinated cones from selections of the Choctawhatchee variety were collected for this purpose. Seedlings planted at relatively close spacing will be thinned at age 5 years. Supplemental tests will aid selection of the best families, and the best individuals within these families will be left for seed production. We anticipate that controlled pollinations can be made in seedling orchards prior to the 10th year in order to provide seedlings for another round of selection.

Greater attention should be given subpopulations away from the main population centers, particularly subpopulations of the Ocala variety. There is ample evidence of the existence of stands with desired characteristics that are superior to those of the main population of the Ocala variety. Such subpopulations may also lack other deficiencies of the Ocala variety yet retain the growth superiority of the Ocala over the Choctawhatchee variety.

Even without genetic improvement, sand pines have the ability to make reasonable growth on sands too poor for other species. The main detraction of the species is its scrubby tree form. Even though its natural range is limited, the species has great variability and many good phenotypes have been located. We confidently expect to produce sand pines of greatly improved tree quality and growth.

LITERATURE CITED

1. Anonymous. 1963. Sand pines do best on sandhills. Fla. For. Serv., Fla. For. Rep. 6(2): 1-4.

2. Barnett, J. P., and McLemore, B. F. 1965. Cone and seed characteristics of sand pine. South. For. Exp. Stn., U. S. For. Serv. Res. Pap. SO-19, 13 pp.

3. Clark, Alexander III, and Taras, M. A. 1969. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part II--Sand pine (Pinus clausa (Chapm.) Vasey). Southeast. For. Exp. Stn., USDA For. Serv. Res. Pap. SE-51, 14 pp.

4. Larson, R. W., and Goforth, M. H. 1961. Florida's timber. USDA For. Serv. Southeast. For. Exp. Stn. For. Surv. Rel. 57, 32 pp.

5. Little, E. L., Jr., and Dorman, K. W. 1952. Geographic differences in cone-opening in sand pine. J. For. 50: 204-205.

6. Morris, J. E. 1967. Racial variation in sand pine seedlings. Ninth South. Conf. For. Tree Improv. Proc. 1967: 132-136.

7. Ross, E. W. 1970. Sand pine root-rot--Pathogen: Clitocybe tabescens. J. For. 68: 156-158.

8. Zelawski, W., and Strickland, R. K. 1973. Temperature effects on growth, assimilation, and bud development of sand pine. In Sand pine symposium proceedings 1972. USDA For. Serv. Southeast. For. Exp. Stn.

FINGERPRINTING SUPERIOR GROWTH IN SAND PINE

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Abstract.--Electrophoretically separated protein from nonsuperior Ocala sand pines consistently contained fractions that were absent in the protein from superior trees; these fractions were between Rf 0.29 and 0.39 of the polyacrylamide gel. Absence of fractions within this range suggests a genetic marker of superior growth. Neither the migration rate nor enzymic activity of glucose-6-phosphate dehydrogenase or malate dehydrogenase (MDH) isoenzymes provided a marker for rapid growth in superior sand pines. The migration rate of MDH isoenzymes and protein fractions, the activity of MDH isoenzymes, and the quantity of protein in protein fractions appeared to be influenced by a number of factors, not least of which were age, environment, soil, and genetics. Hypotheses concerning these factors and that of the genetic marker await confirmation.

INTRODUCTION

Superior wood-producing trees are fast growing and have a desirable morphology. They are sought and propagated principally to shorten the rotation age of plantations, i.e., the time needed for planted trees to reach an optimum, merchantable size. Selection of superior trees is based primarily on comparisons between the candidate and neighboring trees of the same species and age in the forest. True superiority is adjudged by the ability of progeny of grafted stock to exhibit superior characteristics similar to those of the selected candidate. The approach is sound but very time-consuming.

Much time and work would be saved if candidate trees could be screened for the rapid-growth characteristic before they ever left the forest. This screening should be possible. Tree growth is cumulative and genetically controlled. Assimilation, the basic growth process, depends upon the speed and duration of certain biochemical reactions. Enzymes are organic catalysts that control the rate of these reactions and the rate at which a tree grows. Therefore, differences between the rate at which superior and nonsuperior trees grow in a given locality should be reflected by the activity of enzymes controlling these reactions. Enzymic activity would thus serve as an index of growth and a means of ascertaining that a candidate tree does have detectable, genetically transmittable attributes for rapid growth.

This paper summarizes results of experiments leading to the possible detection of a genetic indicator of superior growth and to associated factors.

METHODS

Procedures and techniques used in these experiments are tedious but not complicated. Specific details of the methods used with appropriate references are reported elsewhere (1). A synopsis of significant methodology, references, and results follows.

The work was carried out in two parts. The first series of experiments was designed to identify the metabolic pathways and enzymes involved in the photosynthetic fixation of carbon. Ocala sand pine (Pinus clausa var. clausa Ward) seedlings grown from nonsuperior tree seed were exposed to radioactively labeled carbon dioxide ($^{14}CO_2$) under controlled time, temperature, and light intensity. Radioactivity of sugars, organic acids, and amino acids in ethanol extracts prepared from green tissue of seedlings was measured, components of each of the three fractions were identified, and the relative amount of radioactive carbon in each compound was compared.

A second series of experiments measured the activity of some of these enzymes in the green tissue of five parent trees judged superior by tree improvement personnel of the University of Florida, private industry, the Florida Forest Service, and the U. S. Forest Service and in the green tissue of 25 neighboring parent trees that were nonsuperior. Included in this series of experiments were 50 half-sibling progeny from each superior and nonsuperior parent tree; half of those progeny were grown in pots of Paola sand and half in pots of Lakeland coarse sand (for a total of 1,500 half-sibs). Because direct measurement was thwarted by the presence of endogenous polyphenols, quinones, resins, etc., in the extract, the following indirect approach was adopted.

Proteins were extracted from acetone powders of green tissue (5), and these were separated electrophoretically in polyacrylamide gels. Protein fractions were stained with coomassie blue, and the isoenzymes of glucose-6-phosphate dehydrogenase (G-6-PDH) and of malate dehydrogenase (MDH) were stained by using coupled reactions leading to reduced nitroblue tetrazolium. The intensity of the coloration obtained with these techniques is related to the activity of the enzyme (4) and to the quantity of protein (3). Protein fractions and isoenzymes were identified by the distance each had migrated through the gel with respect to a dye front (Rf-value) and were quantified from densitometer tracings of scanned gels. These data were then analyzed statistically.

RESULTS AND DISCUSSION

In the first series of experiments, the sugar fraction contained 75 percent of the radioactively labeled carbon, organic acids contained 19 percent, and amino acids contained 6 percent. Glucose, fructose, and, to a lesser extent, galactose in the sugar fraction contained ^{14}C, as did malic acid in the organic acid fraction, and aspartic acid, glutamic acid, and either of the related compounds lysine or arginine of the amino acid fraction.

Sugars constituted the major photosynthates leading to formation of organic and amino acids and, eventually, to protein synthesis. Thus, the data suggested that the glycolytic pathway, the pentose phosphate shunt, and the tricarboxylic acid cycle were mechanisms for interconversion of these compounds. For this reason, the activity of key enzymes along these biochemical pathways was expected to provide an index of superior tree growth for sand pine.

Isoenzymes and protein bands are separate entities. Any one can act as a marker of genetic variation between superior and nonsuperior trees. To be meaningful, however, differences must be consistent in tissue from superior and from nonsuperior trees growing on the same soil. In the second series of experiments, none of the three isoenzymes of G-6-PDH nor any of the six isoenzymes of MDH provided an index of superiority. The two individual comparisons differed statistically, but neither was consistent for all nonsuperior trees.

Some indication of a genetic marker for superior growth was found in data obtained for the protein fractions, however. The mobility of individual proteins within the gel matrix during electrophoresis depends upon their ionic charge and molecular dimensions (2). All things being equal, proteins from trees of similar genetic constitution can be expected to produce a similar number of fractions and similar patterns of protein separation. Proteins from the superior and nonsuperior parent trees used in this study separated into 17 fractions serially arranged along the length of the gel. The pattern of arrangement differed, however, indicating possible genetic variation. Gels of the protein from superior parents had no fractions between Rf 0.29 and 0.39, whereas protein from nonsuperior parents contained one or more fractions within these Rf limits. The difference was consistent among all parent trees but not among their open-pollinated, half-sibling progeny. This pattern suggests either that a genetic marker for superior growth exists and that genes for rapid growth might be recessive, or that pollen from superior trees fertilized only a small proportion of flowers on neighboring nonsuperior trees and that very little "selfing" occurred on superior trees. The latter seems most probable, because all flowers were open-pollinated.

The aforementioned hypothesis is based upon limited experimentation and needs confirmation. If further testing confirms results of this comparison, a relatively few hours of laboratory work can substitute for the years required by progeny testing.

Just as applied nutrients can stimulate growth of a plant, so can external factors influence physiological processes. Statistical data from these experiments indicated that some of the external factors and some of the isoenzymes and protein fractions affected by them could be identified. Such knowledge provides a useful tool for possible future manipulation of physiological processes.

Indications of causal relationships were suggested in the orthogonal comparisons shown in table 1. The possibility of their existence appears to be supported by the following data.

The first comparison utilized data from tissue of 750 half-sibling seedlings grown in a greenhouse on each of two sandhill soils. Because each sample was comprised of tissue from superior and nonsuperior seedlings, the comparison was actually between soils, i.e., Lakeland sand developed under thermic conditions (LT) and Paola sand developed under hyperthermic conditions (PH). For this reason, significant responses were attributed to SOIL factors.

The second comparison was between tissue from 750 half-sibling seedlings grown in a greenhouse on LT and on PH and that from 30 parent trees growing in situ on hyperthermic sand (OH). Significant responses were

Table 1.--Statistical comparisons of differences in malate dehydrogenase (MDH) isoenzymes and protein fractions from tissue of (A) sand pine seedlings grown on one of two soils and (B) sand pine progeny grown on two sandhill soils and their parents grown *in situ*

MDH isoenzymes significantly greater in one of the two sets of tissue as determined by--		Protein fractions significantly greater in one of the two sets of tissue as determined by--	
Rf values[a/] [b/]	Enzymic activity[b/]	Rf values[a/] [b/]	Quantity of protein[b/]
- - - - - - - -	- - - - - - - - Identifying number	- - - - - - - -	- - - - - - - -
A. SEEDLINGS GROWN ON LAKELAND (LT) VS. THOSE GROWN ON PAOLA (PH) SAND			
n. s.	☐ 2*, 3*	n. s.	☐ 7*, 12*, 14**, 16*, 17*
B. SEEDLINGS GROWN ON LT AND PH VS. PARENTS *IN SITU* (OH)			
▨ 2*, 3*, 4**	n. s.	▨ 12*, 16*	▨ 2*, 8*, 15**, ░ 12**, 16*

a/ Rf = $\frac{\text{Distance isoenzyme or protein fraction migrated}}{\text{Distance dye front migrated}}$

b/ n. s. = No significant difference between the two sets of tissue.

* = 5-percent probability of a chance occurrence of greater Rf value or enzymic activity in only one set of tissue.

** = 1-percent probability of a chance occurrence of greater Rf value or enzymic activity in only one set of tissue.

☐ Attributed to soil factors.

▨ Attributed to genetic factors.

░ Attributed to soil and genetic factors.

attributed primarily to GENETIC factors (Sibling vs. Parent) and to a lesser extent to SOIL factors (LT + PH vs. OH). Differences in age of the plants and conditions under which siblings and parents grew undoubtedly contributed to the response, but, because green tissue of the same age and from the same parts of the trees was used and because the comparisons were made with the same isoenzymes and protein fractions, these factors were not considered to be as important as genetic factors.

Results of the two orthogonal comparisons show that migration rates (Rf's) of MDH isoenzymes 2, 3, and 4 and of protein fraction 12 and 16 were significantly greater for seedlings grown in LT and PH than for parents in OH (genetic and soil factors). However, Rf's in the LT vs. PH comparison (soil factor) did not differ significantly; thus, this lack of insignificant difference suggests that genetic factors affected the migration rate of these isoenzymes and protein fractions much more than soil factors. Accordingly, these factors were labeled GENETIC.

Activity of MDH isoenzymes 2 and 3 was significantly higher in seedlings grown in LT than in PH (soil factor) but was not significant in the LT + PH vs. OH comparison as influenced by genetic and soil factors. This pattern suggests that the activity of MDH isoenzymes 2 and 3 was affected more by soil than by genetic factors; otherwise, significant difference also would have appeared in the latter comparison. Activity of MDH isoenzymes was therefore labeled SOIL.

Similarly, the quantity of protein in fractions 7, 12, 14, 16, and 17 was significantly higher in LT than in PH (soil factor). Here, however, the quantity in fractions 12 and 16 also was significantly higher in the LT + PH vs. OH (genetic and soil factor) comparison, as were fractions 2, 8, and 15. This pattern implies that the quantity of protein in some fractions, e.g., 12 and 16, was affected more by soil than by genetic factors. In other fractions, it was affected principally by soil, e.g., 7, 14, and 17. And in still other fractions, it was affected principally by genetic factors, e.g., 2, 8, and 15. All were appropriately labeled.

Validity of the SOIL and GENETIC labels was tested with other statistical data. Comparisons of protein fractions and MDH isoenzymes were made between parent trees on OH and those seedlings growing on PH. PH and OH soils are very similar, if not identical. PH was selected as representative of sands on which the parent trees were located. All soils in that area developed under hyperthermic conditions. For these reasons, the influence of soil factors on isoenzymes and protein fractions was considered negligible. Genetic factors (sibling vs. parents) were of primary importance in these comparisons. If the SOIL and GENETIC labels from previous comparisons were correctly assigned, only those isoenzymes and protein fractions bearing GENETIC labels should appear significant in results of the PH vs. OH comparison.

The labels appear to be correct (table 2, column 5). All isoenzymes and protein fractions bearing a GENETIC label and one with a SOIL + GENETIC label were significant. All those labeled SOIL and one labeled SOIL + GENETIC were nonsignificant. The probability that all 13 isoenzymes and protein fractions bearing a single label would be confirmed strictly by chance, if each is considered an independent and mutually exclusive event, as 1 in 8,192.

Table 2.--Statistical comparison of the factors that appeared to influence specific isoenzymes and protein fractions in the previous test (table 1) with the factors determined from tests of parent trees on OH and progeny growing on PH

(1) Isoenzyme or protein	(2) Item	(3) Isoenzyme or protein fraction	(4) Influencing factor and significance[a] (From table 1)	(5) Sibling vs. parents on similar soils[a] (Genetic factor)
		Identifying No.		
MDH	Rf[b]	2	Genetic *	**
		3	Genetic *	**
		4	Genetic**	**
	Activity	2	Soil *	n. s.
		3	Soil *	n. s.
Protein	Rf[b]	12	Genetic *	**
		16	Genetic *	**
	Quantity	2	Genetic *	**
		7	Soil *	n. s.
		8	Genetic *	**
		12	Soil * + Genetic **	**
		14	Soil **	n. s.
		15	Genetic **	**
		16	Soil * + Genetic *	n. s.
		17	Soil *	n. s.

[a] n. s. = no significant difference.
* = 5-percent probability of a chance occurrence.
** = 1-percent probability of a chance occurrence.

[b] $\mathrm{Rf} = \frac{\text{Distance isoenzyme or protein fraction migrated}}{\text{Distance dye front migrated}}$

SUMMARY

Experiments were conducted to find an index of rapid growth in superior selections of Ocala sand pine. Migration rates and activity of electrophoretically separated isoenzymes of glucose-6-phosphate and malate dehydrogenase (MDH) and the migration rate and quantity in protein fractions from superior and nonsuperior pines were compared. Differences in the migration rate of protein fractions served to differentiate between superior and nonsuperior parent trees but not between their open-pollinated, half-sibling progeny. Some of the factors that appeared to affect the migration rates of MDH isoenzymes and protein fractions, the activity of MDH isoenzymes, and the quantities in protein fractions were tentatively identified. Hypotheses concerning these factors and that of the genetic marker await confirmation.

LITERATURE CITED

1. Burns, R. M. 1971. Enzyme activity as an index of growth superiority of Pinus clausa var. clausa on two soils. Ph.D. Diss., Univ. Fla., 116 pp. (Diss. Abstr. 32: 6150b. 1972.)

2. Davis, B. J. 1964. Disc electrophoresis — II. Method and application to human serum proteins. N.Y. Acad. Sci. Ann. 121: 404-456.

3. Fishbein, W. N. 1972. Quantitative densitometry of 1 - 50 g protein in acrylamide gel slabs with coomassie blue. Anal. Biochem. 46: 388-401.

4. Gabriel, O., and Wang, S. 1969. Determination of enzymatic activity in polyacrylamide gels — I. Enzymes catalyzing the conversion of non-reducing substrates to reducing products. Anal. Biochem. 27: 545-554.

5. Hare, R. C. 1970. Physiology and biochemistry of pine resistance to the fusiform rust fungus, Cronartium fusiforme. Ph.D. Diss., Univ. Fla., 155 pp. (Diss. Abstr. 31: 6370b. 1971.)

INTERSPECIFIC HYBRIDIZATION INVOLVING SAND PINE--PAST ATTEMPTS AND FUTURE POTENTIAL[1]

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Abstract.--Previous results of artificially hybridizing sand pine with Virginia pine and with slash pine are summarized. Results to date indicate that it may be feasible to move sand pine germ plasm into more northerly locations through hybridization with Virginia pine but that tolerance to fusiform rust and mushroom root rot will not be automatically conveyed to slash x sand pine hybrids by their parents. Hybrids between sand pine and other southern pines may be possible, but obtaining commercial production through interspecific hybridization will require long-term investments and commitments.

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INTRODUCTION

Although not now widely used, interspecific hybridization is a technique that eventually must be evaluated in most tree improvement programs. Utility of the technique will depend on a variety of factors, such as the degree and type of variation extant within the species under consideration, the need to develop new types (such as those tolerant to diseases, insects, excessively dry or wet conditions, poor sites, etc.), and the ever present need to increase volume growth and improve wood quality.

It is important to evaluate the potential of interspecific hybridization involving sand pine at this time because of the increasing economic value of the species and because heritable variation in this species of small geographic range and narrow edaphic adaptation is thought to be relatively limited. This paper attempts such an evaluation.

PREVIOUS HYBRIDIZATION RESULTS

Most of the economically important species of southern pines hybridize naturally, and in many instances artificial hybrids can be obtained rather easily (2). This is especially true for the subsection Australes, which includes such species as loblolly pine (Pinus taeda L.), pitch pine (P. rigida Mill.), shortleaf pine (P. echinata Mill.), longleaf pine (P. palustris Mill.), and slash pine (P. elliottii Engelm.). On the other hand, members of the subsection Contortae, which includes two pines with southeastern distributions--Virginia pine (P. virginiana Mill.) and sand pine (P. clausa (Chapm.) Vasey)--are not known to hybridize as extensively. In fact, the only reported hybrid involving Virginia pine is an artificial cross with sand pine (2, 4); one additional hybrid involving the latter species has been reported and that is the interesting inter-subsectional cross of slash x sand pine (9).

Natural hybridization involving sand pine has not been reported to date. This is not surprising considering its limited distribution (3). The shortest distance between populations of sand pine and the related Virginia pine is estimated to be more than 100 miles, although individual trees of Virginia pine may be found closer to sand pine populations (8).

Three successful attempts at artificial hybridization are known. As listed above, one of these is the Virginia x sand pine hybrid and the other two involve crosses of slash x sand pine. It is virtually impossible to determine the total number of attempts that have been made at crossing sand pine with other species because failures are rarely reported. However, Critchfield (2) did list attempts with spruce pine (P. glabra Walt.) and Table-Mountain pine (P. pungens Lamb.) as unsuccessful. He and Goddard et al. (5) also reported obtaining seed from a cross between sand and loblolly pine, but in both cases the seedlings all died soon after germination.

Information being accumulated about the two varieties of sand pine (Ocala and Choctawhatchee) indicates that differences between them may be greater than originally recognized. For example, there is some indication that the Choctawhatchee variety is more resistant to cold and certain insects and diseases; it also seems able to survive planting operations better than the Ocala variety in certain environments (1, 6). As such superiority becomes better understood, strong consideration must be given to differences between the two varieties in parental selections for hybridization. Experience with other species has shown how vital the selection of parental varietie is to hybrid performance.

A number of crosses have been made with sand pine and other species of pine by personnel of the Hoerner-Waldorf Corporation.[2] Although many of these were not successful, seed were obtained from several interesting crosses (a partial summary is given in table 1). Plans have been made to have seedlings obtained from these crosses evaluated to verify hybridity by USDA Forest Service personnel at the Institute of Forest Genetics in Placerville, California.

The successful cross between Virginia and sand pine was produced by personnel at the Institute of Forest Genetics (IFG) at Placerville in 1953. Although information about the parents is limited, it is known that the sand pine pollen used was collected near Pensacola, Florida. Seventeen cones eventually were harvested from the cross, and these contained 366 sound seed and 76 hollow seed, for an average of 21.5 sound seed per cone. Such high seed yields compare favorably with the results of many artificial intraspecific crosses, and if generally obtainable would indicate mass production of this hybrid may be possible. Results from the Hoerner-Waldorf Corporation project (table 1) tend to support this possibility in that they show some of the highest seed yields from this cross (e.g., average of 13.1 sound seed/cone).

Seedlings from the IFG Virginia x sand pine cross were planted in two different locations. Six seedlings were established in the arboretum at Placerville, and a test planting that included 50 hybrid and 37 Virginia pine seedlings (open-pollinated progeny from the female parent of the hybrids) was established in the General Smallwood State Park, Charles County, Maryland. Measurements and observations to confirm hybridity and evaluate performance were made at various periods (4). Some of the observations were as follows.

Authenticity of the hybrids was established on the basis of needle, cone, oleoresin, and "flowering" characteristics. At Placerville, five of

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[2] Personal communication from Ray Brown, Hoerner-Waldorf Corporation, Roanoke Rapids, North Carolina.

Table 1.--Cone and seed yield of eight different interspecific hybrid combinations involving sand pine[a]

Hybrid			Different crosses attempted	Cones at bag removal	Yearling cones	Cones harvested	Total seed	Sound seed	Sound seed/cone
Female		Male							
			Number						
P. taeda	x	*P. clausa*	2	23	18	11	438	75	6.8
P. clausa	x	*P. taeda*	2	9	5	4	5	1	0.3
P. banksiana	x	*P. clausa*	6	62	33	28	8	0	0
P. clausa	x	*P. banksiana*	M[b]	36	30	30	565	12	0.4
P. rigida	x	*P. clausa*	3	15	14	10	75	39	3.9
P. clausa	x	*P. rigida*	2	23	14	9	18	2	0.2
P. pungens	x	*P. clausa*	3	10	4	2	3	2	1.0
P. pinaster	x	*P. clausa*	6	34	13	9	301	65	7.2
P. clausa	x	*P. pinaster*	M[b]	5	6	6	42	0	0
P. echinata	x	*P. clausa*	2	25	20	18	363	29	1.6
P. clausa	x	*P. echinata*	4	22	10	10	51	5	0.5
P. virginiana	x	*P. clausa*	4	84	67	63	1,725	823	13.1
P. clausa	x	*P. virginiana*	6	33	27	26	531	301	11.6
P. thunbergii	x	*P. clausa*	6	233	196	175	1,453	491	2.8
P. clausa	x	*P. clausa*	2	14	14	14	354	178	12.7

[a] Unpublished data, courtesy of Hoerner-Waldorf Corporation.

[b] Number of crosses unknown because a pollen mix was used at least once.

the six hybrids survived for measurement at age 5 when the average height was 5.2 feet; at 10 years, heights ranged from 11.9 to 14.4 feet, with an average of 13.0 feet.

Survival of the Virginia x sand pine hybrids was excellent in Maryland, with 47 trees (94 percent) alive 10 years after planting; survival of the Virginia pine checks was 84 percent. The average height of the hybrids at 6 years was 8.4 feet, which was 15 percent greater than that for the Virginia pine. At age 10, the average hybrid height was 17.6 feet (ranging from 14 to 21 feet), while the average height for Virginia pine was 15.6 feet (ranging from 7 to 19 feet). The hybrids also had larger diameters.

The performance of the Virginia x sand pine hybrids at the Maryland location is important and shows potential. It would not be correct technically to express their performance in terms of hybrid vigor because progeny from the paternal species were not included in the test. Practically, it could be considered as such, however, because sand pine would not be expected to grow well or even to survive that far north. Certainly, the results thus far indicate the feasibility of moving sand pine germ plasm into more northerly locations through hybridization with Virginia pine; this movement could be of value in improving production on some of the poorer, droughty, deep sand sites.

Hybrids involving slash and sand pines have been produced on two separate occasions. Saylor and Koenig (9) reported the production of such hybrids in a large interspecific hybridization program by the Woodlands Research Department of Union Camp Corporation and the North Carolina State University-Industry Cooperative Tree Improvement Program. The slash pine parents for the crosses were superior tree selections located in the Union Camp Seed Orchard, and the sand pine parents were select trees located in the Ocala National Forest.

Eighteen different parent tree combinations were tried in 1962 and again in 1963, but sound seed were obtained from only three crosses. Average yield of sound seed was a meager 0.5 seed per cone for the slash x sand combinations; reciprocal crosses were a complete failure, witn only hollow seed being obtained from a few crosses.

Measurements and observations of the hybrids and open-pollinated progeny from the parental trees of both species were made at 8, 16, and 22 months while the seedlings were growing in a greenhouse. Verification of hybridity, as based on stem, branch, and needle characteristics, was relatively easy. Growth patterns of the three groups changed noticeably over the 22-month measurement period; at the final measurement the hybrids were the tallest, although they were the smallest at 8 months and intermediate at 16 months. Mean measurements for the hybrid, sand, and slash pine seedlings were 54.6 cm., 51.6 cm., and 46.1 cm., respectively, at 22 months.

After the greenhouse study, the five remaining hybrids were planted in the School of Forest Resources arboretum near Raleigh, North Carolina. When planted during the spring of 1966, the hybrids were quite vigorous and remained so until they were damaged by the cold during the winter; from that time on they declined because of cold damage each year until the last one died in 1970. In 1969 several grafts of the hybrids were made on slash pine rootstock at Savannah, Georgia. Graft survival is 75 percent and growth has been good except that two (out of seven) ramets show signs of incompatibility. Unfortunately, the hybrid grafts are susceptible to fusiform rust, as is their slash pine parent; indications of tolerance that could be provided by the sand pine parents have not yet become manifest.

Although not reported previously, a number of slash x sand pine hybrids have been produced by personnel of the tree improvement program of St. Regis Paper Company. In 1966, crosses involving three different parental combinations were attempted. Again superior tree selections were used, and again the sand pine selections were of the Ocala variety. Detailed compatibility data were not recorded, but it was noted that considerable difficulty was encountered.[3/] Seed yield was less than 20 percent of results normally obtained from intraspecific crosses for progeny testing. Only one cross produced enough seed for a complete field test, while a second produced just a few seed, and a third produced no sound seed at all. (Subsequent crosses in 1970 and 1971 appear to be producing results similar to the 1966 crosses.)

Test plantings were established in 1969 at two locations in Florida, at the King Forest in Walton County, and in Hamilton County. The plantings in both areas were on very deep sand sites with index values of less than 60 feet (i.e., base 50 years). Ten replications were established at both locations within which 10 tree row plots of the following species were planted: Slash pine (St. Regis - random seed lot), slash pine (University of Florida - uniform check lot), sand pine (Choctawhatchee variety), longleaf pine (general nursery stock from State nursery), and slash x sand pine hybrids from two crosses.

Survival of the slash x sand pine hybrids was 83 percent at 3 years of age (table 2). This survival was slightly higher than that of one group of slash pine (80 percent) and considerably higher than that of all other checks. Height growth of the hybrids was also impressive in that it was equal to the best of the checks (sand pine), with an overall average of 3.6 feet at 3 years of age.

[3/] Personal communication from H. H. Gresham, Southern Timberlands Division, St. Regis Paper Co., Pensacola, Florida.

Table 2.--Height and survival at age three of slash x sand pine hybrids and four species checks[a]

HAMILTON COUNTY PLANTATION

	Slash pine (St. Regis)		Slash pine (University of Florida)		Sand pine (Choctawhatchee)		Longleaf pine[b]	Slash x sand pine (1)		Slash x sand pine (2)[c]	
Replications	Avg. ht. / plot	Trees/ plot	Avg. ht. / plot	Trees/ plot	Avg. ht. / plot	Trees/ plot	Trees/ plot	Avg. ht. / plot	Trees/ plot	Avg. ht. / plot	Trees/ plot
	Feet	Number	Feet	Number	Feet	Number	Number	Feet	Number	Feet	Number
1	2.9	10	2.4	2	2.7	3	2	2.9	8	3.5	5
2	2.5	9	1.4	1	3.6	6	0	3.1	7	2.9	8
3	3.6	3	2.8	2	3.6	4	0	3.6	8	2.7	6
4	3.3	9	3.3	1	3.0	9	1	3.5	9	--	--
5	3.9	9	2.8	6	3.7	7	0	3.3	9	--	--
6	3.0	6	3.0	5	3.0	4	1	4.0	8	--	--
7	3.4	8	3.7	7	2.8	5	0	3.7	9	--	--
8	3.2	8	2.3	2	1.8	5	1	3.8	10	--	--
9	3.3	9	3.0	4	2.8	4	5	2.9	9	--	--
10	4.1	9	2.8	3	2.7	3	3	3.9	8	--	--
Avg. / replication	3.3	8.0	2.8	3.3	3.0	5.0	1.3	3.5	8.5	3.0	6.3
WALTON COUNTY PLANTATION											
1	3.7	8	4.2	5	3.6	4	5	3.5	8	--	--
2	3.6	6	3.3	6	4.1	3	1	3.7	10	--	--
3	3.0	10	2.5	3	4.1	4	6	4.8	10	--	--
4	4.1	9	3.4	7	5.3	8	2	4.2	7	--	--
5	3.4	10	2.7	5	4.0	3	2	3.3	8	--	--
6	2.8	8	3.4	4	4.2	3	3	3.6	7	--	--
7	2.8	9	3.0	8	4.5	3	4	2.4	10	2.6	10
8	2.5	8	3.8	8	4.0	3	7	3.9	7	3.9	9
9	3.4	7	2.8	6	4.4	5	2	3.6	6	--	--
10	4.4	6	2.7	4	3.4	7	4	3.7	8	3.8	7
Avg. / replication	3.4	8.1	3.2	5.6	4.2	4.3	3.6	3.7	8.1	3.4	8.7
Overall avg. ht.	3.3		3.0		3.6			3.6		3.2	
		Percent		Percent		Percent	Percent		Percent		Percent
Overall survival		80		45		46	25		83		75

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[a] Unpublished data courtesy of St. Regis Paper Company.

[b] Because of grass stage, seedlings were too small to measure.

[c] Only enough seedlings of this cross were available for six rows.

The slash x sand pine cross might be a hybrid combination of value, considering its excellent survival characteristics and growth performance, which to date has at least equaled that of the better parent (sand pine). In addition, there is a good chance that the wood specific gravity of the hybrid will be increased significantly above that of sand pine because values for slash pine are so high (e.g., 0.43 versus 0.56 for sand and slash pine, respectively). This is a major objective of the St. Regis Paper Company's hybridization project, but the hybrids are still too small to determine specific gravity.

According to present crossability data, mass production of slash x sand pine F_1 progeny may not be economically feasible. However, one means of possibly overcoming this drawback is to go to a system of backcrossing from the hybrid to the sand pine parent. Through proper selection, this system also offers greater opportunity for developing trees that more closely resemble the desired sand pine parents while incorporating the useful characteristics of the slash pine parent.

Results to date indicate that tolerance to fusiform rust will not be conveyed automatically to the slash x sand pine hybrids from the sand pine parent, nor will complete tolerance to mushroom root rot (Clitocybe tabescens) be provided by the slash pine parent. Thus, careful attention must be given these characteristics when selecting parental trees for the initial crosses. As with other features, backcrossing may be the best means of obtaining the desired combination of traits.

Of the verified sand pine hybrids, the Virginia x sand pine combination appears to have the greatest utility in extending the range of sand pine germ plasm into the colder, more northerly regions. Tests involving crosses from superior tree parents seem appropriate for the deep sand sites (especially in the coastal regions) that exist from Florida to Maryland. Although the chance for increasing volume production on these nonproductive sites appears good, little can be done to increase wood specific gravity of the hybrid because the parental species are so similar.

Hybrids between sand pine and other species of southern pines may be possible, considering the fact that one inter-subsectional cross involving sand pine has already been documented and seed have at least been obtained from several others. Crosses of sand pine with shortleaf and loblolly pines could be of special significance for commercial production in southeastern regions of the United States. The possibility of growing loblolly-like trees on the currently nonproductive deep sand sites seems particularly attractive in light of predicted increased needs for wood in the future.

Yet it is important to emphasize again that obtaining commercial production through interspecific hybridization in most cases will require long-term investments and commitments. Initial efforts will almost invariably

Degree of infection by *Cronartium fusiforme* was evaluated for the Hamilton County plantation. No fusiform rust was observed on the sand and longleaf pine checks, while it was rather prevalent among the slash pine checks (6.2 percent and 35.4 percent of the trees had bole and limb infections, respectively). For the hybrids, 4.8 percent had bole infections while 18.3 percent had limb infections. In this case, it appears that some resistance to fusiform rust may have been provided the hybrids by the sand pine parent.

POTENTIAL USE OF SAND PINE HYBRIDS

Thus far, interspecific hybridization has not been widely used operationally in forestry. This disuse undoubtedly is related to the fact that, historically, wood has been in plentiful supply in many regions of the world and that most economically important tree species contain a wealth of intraspecific variation. As a result, tree improvement efforts have been wisely concentrated on utilizing the within-species variation through selection and breeding programs rather than on improvement through the more costly and time-consuming approach of hybridization between species.

The primary objective of interspecific hybridization is to produce trees with unique combinations of traits not found in the parental species. Such combinations allow these hybrids to be used for specific purposes. Important benefits might be better adaptation to adverse sites, extension of the commercial range of valuable species, greater tolerance to insects and diseases, etc. Certain southern pine hybrids have already demonstrated suc benefits. Examples include (a) the pitch x loblolly pine hybrid adapted to sites with poorer soils and colder temperatures than those favorable for loblolly pine, and (b) the loblolly x shortleaf pine hybrid for resistance to fusiform rust.

It is difficult at this time to determine what value interspecific hybridization involving sand pine might have. However, certain factors and conditions indicate that further efforts may be warranted, even though the results are likely to be of greater value academically than they are in immediately enhancing commercial production.

The most outstanding feature of sand pine for production forestry is its ability to grow well on deep, sandy soils where other species do poorly (1, 6, 7). Consequently, it is now recognized as an important comme cial species, especially by the pulp and paper industry.

On the other hand, two features that restrict utilization of the speci include its limited geographic range and its relatively low wood specific gra ity. Through a program of selection and interspecific hybridization, however, these restrictions might be overcome at the same time the above exce tional attribute is exploited.

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Program Manual
or Producing Weight-Scaling Conversion Tables

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Program Manual
for Producing Weight-Scaling Conversion Tables

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Weight-scaling--weighing truckloads of timber to determine volume--is much faster and cheaper than scaling individual pieces (7, 8, 11). Simple rules of thumb that convert weights into sawtimber or veneer volumes are usually insufficient over short periods, however, because they cannot account for the high variation common in individual loads or in small tracts. Long-log and tree-length logging increase the problems in applying rules of thumb because volumes of a variety of products must be estimated for individual truckloads.

Researchers have developed techniques for accurately estimating volumes of various products on individual loads when the weight and the number of trees on the load are known (2, 9, 10). These techniques have been tailored to long-log and tree-length logging (1, 3, 4, 6), and to the merchantability limits of individual firms.

This manual presents a computerized system that will yield weight-scaling estimates for individual firms. The system is flexible enough to accommodate normal logging techniques while producing scale estimates for any combination of three basic roundwood products: veneer logs, sawmill logs, and pulpwood. It is geared directly to inventory control and allocation of raw material to processing centers and includes a program which helps relate scaling data to prospective stumpage sales and harvesting operations. Details of the development of the statistical

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models have already been reported (3). Three programs are provided. Program WTVOL generates estimates of veneer volumes, sawmill volumes, and pulpwood volumes in any combination desired. Program CHECK uses regression coefficients developed by WTVOL plus weight-volume data from periodic check scales to calculate volume and percentage differences between estimated and observed volumes. Program VOLWT estimates average total and saw-log weights by form class, d.b.h., and number of usable 16-foot logs from volume per tree and average tree length. These tables can be related back to earlier stumpage sales and harvests.

Description of Linear Models

Earlier reports show that linear regression models can provide reliable estimates for this weight-scaling system. The general form of the equations for programs WTVOL and CHECK is:

$$Y_i = b_{0i} + b_{1i}NT + b_{2i}WT + b_{3i}(WT \times NT)^{\frac{1}{2}}$$

where

Y_i = either veneer volume, total saw-log volume, or total saw-log weight.

NT = number of trees, long logs or short logs per load (not mixed).

WT = total net weight of the load.

In program VOLWT the form is:

$$Y_i = b_{0i} + b_{1i}AV + b_{2i}AL$$

where

Y_i = either average total weight or average saw-log weight per tree.

and

AV = average volume per tree.

AL = average length per tree (number of usable 16-foot logs).

A number of models were tested but those indicated above were consistently better in estimating the dependent variables and were judged to be of higher practical value. Freese's manual (5) describes the stepwise regression procedures by which the models were developed.

Not all estimates produced by the programs described here are generated directly by regression. For instance, where estimates are desired for sawtimber and pulpwood from tree-length material, sawtimber weights are generated by regression, but pulpwood weights are calculated by subtracting estimated sawtimber weight from total weight. Such estimates are simpler and more consistent. Similarly, where estimates are desired for veneer, sawmill, and pulpwood volumes, total sawtimber volume and veneer volume are estimated by regression, and sawmill volumes are estimated by the difference between the two regression estimates.

Data Handling and Management

Data required to produce conversion tables are:

1. Total board-foot volume (sawmill plus veneer volume).
2. Sawmill volume.
3. Veneer volume.
4. Total weight (all products).
5. Pulp weight.
6. Number of trees, long logs, or short logs (not mixed).

These data are collected for each load and recorded as indicated by exhibits 1 and 2. Other data are required by the three programs included here, but these special data requirements are noted in the discussions of the individual programs.

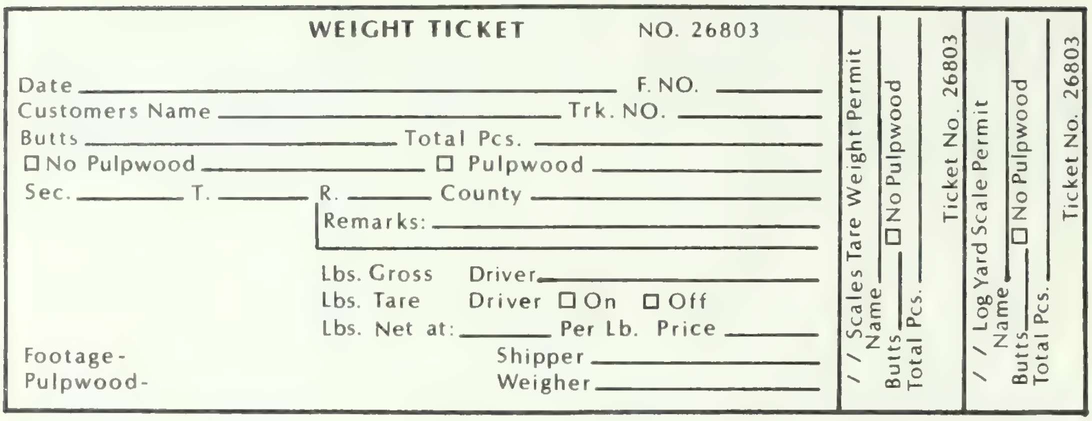
Keypunch formats for the data are shown in Appendix 4. None of the programs discussed here edit input data; therefore, considerable care must be taken in recording and keypunching.

Estimating Volumes from Weight

Program WTVOL is the cornerstone of this system; it provides estimates of product volumes. The program permits users to choose from five options depending on logging technique and product raw materials. These options are:

1. Long or short logs
    - a. Sawtimber only (option 1).
    - b. Veneer only (option 2).
    - c. Sawmill and veneer logs (option 3).
2. Tree-length logs
    - a. Sawtimber and pulpwood (option 4).
    - b. Veneer, sawmill, and pulpwood (option 5).

Exhibit 1. Weight ticket



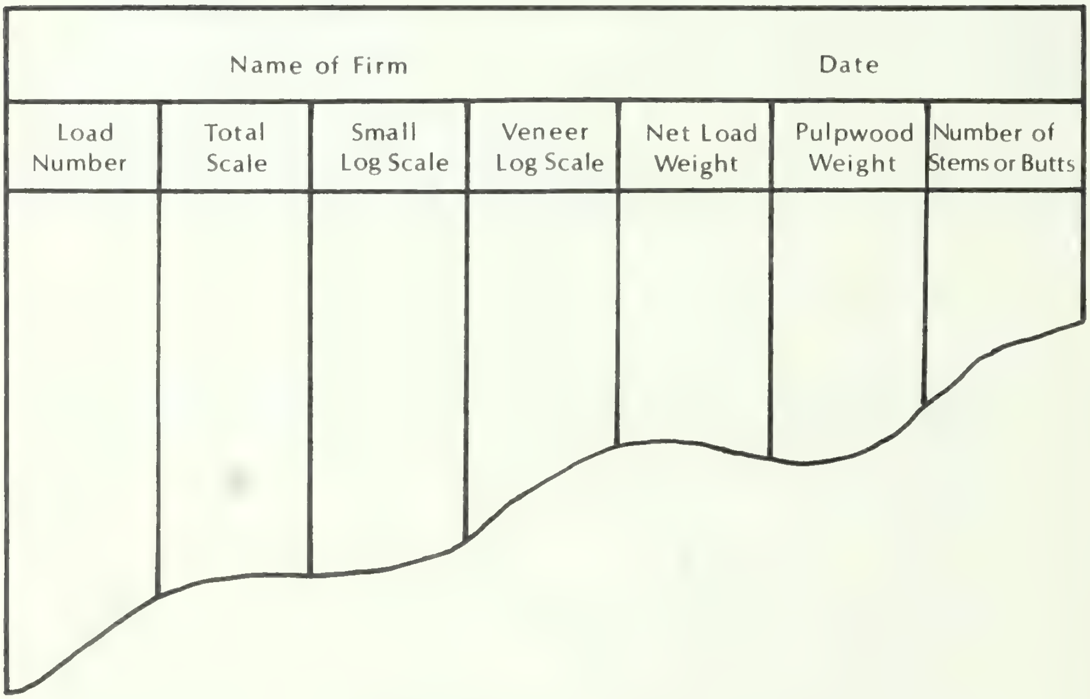
WEIGHT TICKET NO. 26803

Date F. NO.
Customers Name Trk. NO.
Butts Total Pcs.
☐ No Pulpwood ☐ Pulpwood
Sec. T. R. County
Remarks:
Lbs. Gross Driver
Lbs. Tare Driver ☐ On ☐ Off
Lbs. Net at: Per Lb. Price
Footage - Shipper
Pulpwood - Weigher

/ / Scales Tare Weight Permit
Name
Butts ☐ No Pulpwood
Total Pcs.
Ticket No. 26803

/ / Log Yard Scale Permit
Name
Butts ☐ No Pulpwood
Total Pcs.
Ticket No. 26803

Exhibit 2. Data collection form



Name of Firm Date

Load Number	Total Scale	Small Log Scale	Veneer Log Scale	Net Load Weight	Pulpwood Weight	Number of Stems or Butts

The input data decks for this program are:

1. Name header card--for firm name, dates, tract identification, or any other information needed to identify the tables.
2. Option card[1]
    a. Option code (1-5 as described previously).
    b. Pounds per cord of pulpwood conversion.
    c. Minimum number of trees for which a table is desired.
    d. Maximum number of trees for which a table is desired.
    e. Minimum net load weight to appear on each table.
    f. Maximum net load weight to appear on each table.
3. Truckload data cards
    a. Identification.
    b. Total volume (veneer and sawmill).
    c. Sawmill volume.
    d. Veneer volume.
    e. Total net load weight.
    f. Pulp weight.
    g. Number of trees, long logs, or short logs.
4. Trailer card--blank if other data sets follow; 9999 in columns 1-4 if no other data follow.

These decks make up one complete data set and WTVOL requires that these cards all be present and in the order noted. Since firms usually are receiving timber from several tracts whose average timber sizes may vary considerably, WTVOL is programed to produce multiple sets of tables in a single run. The maximum number of sets of tables that can be produced in one run is limited only by the specific requirements of the computer system developing the tables. In producing a set of tables, the program reads a set of header control cards then reads basic data cards until a trailer card is encountered. Next, regression analysis is performed and tables are generated. If the trailer card previously encountered is blank in the first four columns, the program reads the next set of header cards and basic data cards and produces a second set of tables. This sequence is followed until a trailer card is encountered with the value 9999 in columns 1 through 4, which indicates the last data set.

---

[1] Items (b) through (f) of the option card may be left blank. Where (b) is left blank, pulpwood will be tabulated in pounds rather than cords. Where (c) through (f) are left blank, the program will produce tables based on the actual ranges of number of trees and net load weight observed in the sample data.

Once the name card and option card are read, the regression analysis is begun and sums of squares and products are developed as each truckload data card is read. After all cards are read, the regression equations are developed and the tables are generated by substituting values for number of trees and total net load weight. Table range is limited by the minimum and maximum values for number of trees and net load weight shown in the option card or as calculated from the sample data when minimum and maximum values are not shown in the option card. This sequence is followed for all sets of input data.

The form of the output from WTVOL depends upon the nature of the raw material and the consequent option chosen. Each set of volume tables is preceded by a summary sheet showing means and standard deviations, regression equations developed, and the coefficients of determination (R^2) and standard errors associated with each equation. An example of this summary page is shown in exhibit 3. Tables showing volumes by weight follow the summary page and are illustrated for all options in exhibits 4 through 8.

To use these tables, record net load weight and number of trees or logs for each truckload. Refer to the table corresponding with the number of trees or logs recorded, go down the left-hand column to find weight in thousands of pounds, and finally go across this row to locate the volume(s) shown under weight in hundreds of pounds. Note that weights are shown to the nearest even hundred pounds which should be sufficient for most applications. When further precision is required, users should interpolate or use net weight and number of trees (or logs) in the regression equations shown on the summary page to calculate volumes directly.

Appendix 3a indicates the deck setup for this program, a program listing is shown in Appendix 2a, all input data formats are shown in Appendix 4, and definitions of the variable names are given in Appendix 1. As indicated in Appendix 3a, program WTVOL also uses two supporting subroutines, MATINV and MULT, in developing the regression analysis. These subroutines are briefly discussed in a following section.

Check-Scaling

Once WTVOL has been applied to initial sample data, this weight-scaling system may be regarded operative if the firm's limits of precision have been met. But constant checks are essential to determine continuing accuracy of the system and to demonstrate its integrity. For this purpose, truckload samples should be continually taken and program CHECK can then be applied.

CHECK compares actual measured volumes of truckload samples (check-scale samples) with tabular volumes generated by WTVOL from the base data. The CHECK program reproduces tabular values from the weight/volume tables by calculating the weights and volumes with the

Exhibit 3. Summary page of WTVOL output

```
                         WEIGHT SCALING OF TREES FOR VENEER,SAWMILL AND PULPWOOD VOLUME



    NAME OF FIRM OR ORGANIZATION



    NUMBER OF LOADS      =   10  (NO.)

                        MEAN                        STANDARD DEVIATION

    NUMBER OF TREES =   34.9000  (NO.)                       6.8223  (NO.)
    PULPWOOD VOLUME =    2.7629  (CORDS)                     1.2612  (CORDS)
    PULPWOOD WEIGHT =   14.7813  (MLBS)                      6.7473  (MLBS)
    SAWMILL VOLUME  =    0.9569  (MBF)                       0.3045  (MBF)
    VENEER VOLUME   =    1.2246  (MBF)                       0.5948  (MBF)
    TOTAL WEIGHT    =   55.7380  (MLBS)                      9.1239  (MLBS)
    SAWLOG WEIGHT   =   40.9567  (MLBS)                      5.1091  (MLBS)

    THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG VOLUME IS

TOTAL SAWLOG VOLUME =    1.1071 +    0.5674 (NO OF TREES) +    0.3932 (TOTAL WEIGHT) +   -0.9250 (SQRT(TOTAL WEIGHT * NO OF TREES))

    MULTIPLE R SQUARED =     0.8736
    STANDARD ERROR =    0.1656



    THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG WEIGHT IS

TOTAL SAWLOG WEIGHT =   19.2999 +    5.2443 (NO OF TREES) +    3.9024 (TOTAL WEIGHT) +   -8.6234 (SQRT(TOTAL WEIGHT * NO OF TREES))

    MULTIPLE R SQUARED =     0.8584
    STANDARD ERROR =    2.3546



    THE REGRESSION EQUATION FOR ESTIMATING TOTAL VENEER VOLUME IS

VENEER VOLUME =    1.3769+    0.5570 (NO OF TREES) +    0.4117 (TOTAL WEIGHT) +   -0.9682 (SQRT(TOTAL WEIGHT * NO OF TREES))

    MULTIPLE R SQUARED =     0.7958
    STANDARD ERROR =    0.3292
```

same linear regression equations that were used in the table-generating program, WTVOL. The coefficients for these equations are printed on the summary page at the beginning of the WTVOL output.

Input for the CHECK program is:

1. Name header card--same as name card identification for WTVOL.

2. Option card--the program handles five options which are identified on this card, and are the same as those outlined for WTVOL. This card also contains the weight per cord of pulpwood being used for options 4 and 5.

3. Linear regression equation coefficients card--coefficients must be read in the order noted below.

    a. Option 1 requires only one card (the constant and regression coefficients for total saw-log volume).

    b. Option 2 requires only one card (the constant and regression coefficients for veneer-log volume).

    c. Option 3 requires two cards (the constant and regression coefficients for total saw-log volume and total veneer volume).

    d. Option 4 requires two cards (the constant and regression coefficients for total saw-log volume and total saw-log weight).

    e. Option 5 requires three cards (the constant and regression coefficients for total saw-log volume, total saw-log weight, and total veneer volume).

4. Truckload data cards--same as truckload data cards for WTVOL.

5. Trailer card--same as trailer card in WTVOL.

In CHECK, no calculations are made until the first truckload data card is read. At that time tabular values are developed using the constant and regression coefficients and the values for number of trees and total net weight read from the truckload data card. These values are subtracted from the measured check-scale volumes on the truckload data card. These differences are printed on the output, added into summary areas, and the next truckload data card is read. After all check-scale cards are read, percentage differences are computed and printed along with actual differences.

Exhibit 4. Example of table for sawmill-only option

```
     NAME OF FIRM OR ORGANIZATION                                                                30 LOGS
                                                           HUNDREDS OF POUNDS
   THOUS.        0                  2                  4                  6                  8
     OF      SAWTIMBER          SAWTIMBER          SAWTIMBER          SAWTIMBER          SAWTIMBER
   POUNDS      (MBF)              (MBF)              (MBF)              (MBF)              (MBF)
     30        2.173              2.160              2.146              2.133              2.120
     31        2.108              2.096              2.084              2.072              2.061
     32        2.050              2.039              2.028              2.018              2.008
     33        1.998              1.989              1.980              1.971              1.962
     34        1.954              1.946              1.938              1.930              1.923
     35        1.916              1.909              1.902              1.896              1.890
     36        1.884              1.878              1.873              1.867              1.862
     37        1.858              1.853              1.849              1.845              1.841
     38        1.837              1.834              1.830              1.827              1.824
     39        1.822              1.819              1.817              1.815              1.814
     40        1.812              1.811              1.809              1.808              1.808
     41        1.807              1.807              1.806              1.806              1.807
     42        1.807              1.808              1.808              1.809              1.810
     43        1.812              1.813              1.815              1.816              1.818
     44        1.821              1.823              1.825              1.828              1.831
     45        1.834              1.837              1.841              1.844              1.848
     46        1.852              1.856              1.860              1.864              1.869
     47        1.873              1.878              1.883              1.888              1.893
     48        1.899              1.904              1.910              1.916              1.922
     49        1.928              1.935              1.941              1.948              1.954
     50        1.961              1.968              1.976              1.983              1.990
     51        1.998              2.006              2.014              2.022              2.030
     52        2.038              2.047              2.055              2.064              2.073
     53        2.082              2.091              2.100              2.109              2.119
     54        2.129              2.138              2.148              2.158              2.168
     55        2.179              2.189              2.199              2.210              2.221
     56        2.232              2.243              2.254              2.265              2.276
     57        2.288              2.299              2.311              2.323              2.335
     58        2.347              2.359              2.371              2.384              2.396
     59        2.409              2.422              2.434              2.447              2.460
     60        2.474              2.487              2.500              2.514              2.527
     61        2.541              2.555              2.569              2.583              2.597
     62        2.611              2.626              2.640              2.654              2.669
     63        2.684              2.699              2.714              2.729              2.744
     64        2.759              2.774              2.790              2.805              2.821
     65        2.837              2.853              2.869              2.885              2.901
     66        2.917              2.933              2.950              2.966              2.983
```

Exhibit 5. Example of table for veneer-only op[illegible]

NAME OF FIRM OR ORGANIZATION [illegible]

HUNDREDS OF POUNDS

THOUS. OF POUNDS	0 VENEER (MBF)	2 VENEER (MBF)	4 VENEER (MBF)	6 VENEER (MBF)	8 VENEER (MBF)
30	1.392	1.378	1.364	1.350	1.337
31	1.324	1.311	1.299	1.287	1.275
32	1.263	1.252	1.241	1.230	1.220
33	1.219	1.200	1.190	1.181	1.172
34	1.163	1.155	1.147	1.139	1.131
35	1.123	1.116	1.109	1.103	1.096
36	1.090	1.084	1.079	1.073	1.068
37	1.063	1.058	1.054	1.049	1.045
38	1.042	1.038	1.035	1.032	1.029
39	1.026	1.023	1.021	1.019	1.017
40	1.016	1.014	1.012	1.012	1.011
41	1.011	1.010	1.010	1.010	1.010
42	1.011	1.011	1.012	1.013	1.014
43	1.016	1.017	1.019	1.021	1.023
44	1.025	1.028	1.031	1.033	1.036
45	1.040	1.043	1.047	1.050	1.054
46	1.058	1.062	1.067	1.071	1.076
47	1.081	1.086	1.091	1.097	1.102
48	1.108	1.114	1.120	1.126	1.132
49	1.139	1.146	1.152	1.159	1.167
50	1.174	1.181	1.189	1.196	1.204
51	1.212	1.221	1.229	1.237	1.246
52	1.255	1.263	1.272	1.282	1.291
53	1.300	1.310	1.320	1.329	1.339
54	1.349	1.360	1.370	1.381	1.391
55	1.402	1.413	1.424	1.435	1.446
56	1.458	1.469	1.481	1.493	1.505
57	1.517	1.529	1.541	1.554	1.566
58	1.579	1.591	1.604	1.617	1.630
59	1.644	1.657	1.671	1.684	1.698
60	1.712	1.726	1.740	1.754	1.768
61	1.782	1.797	1.812	1.826	1.841
62	1.856	1.871	1.886	1.901	1.917
63	1.932	1.948	1.964	1.979	1.995
64	2.011	2.027	2.044	2.060	2.076
65	2.093	2.109	2.126	2.143	2.160
66	2.177	2.194	2.211	2.228	2.246

Exhibit 6. Example of table for veneer and sawmill option

```
   NAME OF FIRM OR ORGANIZATION                                                                                   30 LOGS
                                                                      HUNDREDS OF POUNDS
 THOUS.                 0                         2                         4                         6                         8
   OF      VENEER       SAWMILL       VENEER       SAWMILL      VENEER       SAWMILL      VENEER       SAWMILL      VENEER       SAWMILL
 POUNDS    (MBF)        (MBF)         (MBF)        (MBF)        (MBF)        (MBF)        (MBF)        (MBF)        (MBF)        (MBF)
   30      1.392        0.781         1.378        0.782        1.364        0.782        1.350        0.783        1.337        0.783
   31      1.324        0.784         1.311        0.784        1.299        0.785        1.287        0.786        1.275        0.786
   32      1.263        0.787         1.252        0.787        1.241        0.787        1.230        0.788        1.220        0.788
   33      1.210        0.789         1.200        0.789        1.190        0.790        1.181        0.790        1.172        0.790
   34      1.163        0.791         1.155        0.791        1.147        0.791        1.139        0.792        1.131        0.792
   35      1.123        0.792         1.116        0.793        1.109        0.793        1.103        0.793        1.096        0.793
   36      1.090        0.794         1.084        0.794        1.079        0.794        1.073        0.794        1.068        0.794
   37      1.063        0.795         1.053        0.795        1.054        0.795        1.049        0.795        1.045        0.795
   38      1.042        0.795         1.038        0.796        1.035        0.796        1.032        0.796        1.029        0.796
   39      1.026        0.796         1.023        0.796        1.021        0.796        1.019        0.796        1.017        0.796
   40      1.016        0.796         1.014        0.796        1.013        0.796        1.012        0.796        1.011        0.796
   41      1.011        0.796         1.010        0.796        1.010        0.796        1.010        0.796        1.010        0.796
   42      1.011        0.796         1.011        0.796        1.012        0.796        1.013        0.796        1.014        0.796
   43      1.016        0.796         1.017        0.796        1.019        0.796        1.021        0.795        1.023        0.795
   44      1.025        0.795         1.028        0.795        1.031        0.795        1.033        0.795        1.036        0.795
   45      1.040        0.794         1.043        0.794        1.047        0.794        1.050        0.794        1.054        0.794
   46      1.059        0.793         1.062        0.793        1.067        0.793        1.071        0.793        1.076        0.792
   47      1.081        0.792         1.086        0.792        1.091        0.792        1.097        0.791        1.102        0.791
   48      1.108        0.791         1.114        0.791        1.120        0.790        1.126        0.790        1.132        0.790
   49      1.139        0.789         1.146        0.789        1.152        0.789        1.159        0.788        1.167        0.788
   50      1.174        0.788         1.181        0.787        1.189        0.787        1.196        0.786        1.204        0.786
   51      1.212        0.786         1.221        0.785        1.229        0.785        1.237        0.784        1.246        0.784
   52      1.255        0.784         1.263        0.783        1.272        0.783        1.282        0.782        1.291        0.782
   53      1.300        0.781         1.310        0.781        1.320        0.780        1.329        0.780        1.339        0.780
   54      1.349        0.779         1.360        0.779        1.370        0.778        1.381        0.778        1.391        0.777
   55      1.402        0.777         1.413        0.776        1.424        0.776        1.435        0.775        1.446        0.774
   56      1.458        0.774         1.469        0.773        1.481        0.773        1.493        0.772        1.505        0.772
   57      1.517        0.771         1.529        0.771        1.541        0.770        1.554        0.769        1.566        0.769
   58      1.579        0.768         1.591        0.768        1.604        0.767        1.617        0.766        1.630        0.766
   59      1.644        0.765         1.657        0.764        1.671        0.764        1.684        0.763        1.698        0.763
   60      1.712        0.762         1.726        0.761        1.740        0.761        1.754        0.760        1.768        0.759
   61      1.782        0.759         1.797        0.758        1.812        0.757        1.826        0.757        1.841        0.756
   62      1.856        0.755         1.871        0.754        1.886        0.754        1.901        0.753        1.917        0.752
   63      1.932        0.752         1.948        0.751        1.964        0.750        1.979        0.749        1.995        0.749
   64      2.011        0.748         2.027        0.747        2.044        0.746        2.060        0.746        2.076        0.745
   65      2.093        0.744         2.109        0.743        2.126        0.743        2.143        0.742        2.160        0.741
   65      2.177        0.740         2.194        0.739        2.211        0.739        2.228        0.738        2.246        0.737
```

Exhibit 7. Example of table for sawmill and pulpwood option

NAME OF FIRM OR ORGANIZATION 30 TREES

THOUS. OF POUNDS	HUNDREDS OF POUNDS 0 SAWTIMBER (MBF)	PULP (CORDS)	2 SAWTIMBER (MBF)	PULP (CORDS)	4 SAWTIMBER (MBF)	PULP (CORDS)	6 SAWTIMBER (MBF)	PULP (CORDS)	8 SAWTIMBER (MBF)	PULP (CORDS)
30	2.173	0.0	2.160	0.0	2.146	0.0	2.133	0.0	2.120	0.0
31	2.108	0.0	2.096	0.0	2.084	0.0	2.072	0.0	2.061	0.0
32	2.050	0.0	2.039	0.0	2.028	0.0	2.018	0.0	2.008	0.0
33	1.998	0.0	1.989	0.0	1.980	0.0	1.971	0.0	1.962	0.0
34	1.954	0.019	1.946	0.061	1.938	0.104	1.930	0.145	1.923	0.187
35	1.916	0.228	1.909	0.268	1.902	0.308	1.896	0.348	1.890	0.387
36	1.884	0.426	1.878	0.464	1.873	0.502	1.867	0.540	1.862	0.577
37	1.858	0.614	1.853	0.651	1.849	0.687	1.845	0.722	1.841	0.758
38	1.837	0.793	1.834	0.827	1.830	0.861	1.827	0.895	1.824	0.928
39	1.822	0.961	1.819	0.994	1.817	1.026	1.815	1.058	1.814	1.090
40	1.812	1.121	1.811	1.152	1.809	1.183	1.808	1.213	1.808	1.243
41	1.807	1.272	1.807	1.302	1.806	1.331	1.806	1.359	1.807	1.387
42	1.807	1.415	1.808	1.443	1.808	1.470	1.809	1.497	1.810	1.524
43	1.812	1.550	1.813	1.576	1.815	1.601	1.816	1.627	1.818	1.652
44	1.821	1.677	1.823	1.701	1.825	1.725	1.828	1.749	1.831	1.773
45	1.834	1.796	1.837	1.819	1.841	1.841	1.844	1.864	1.848	1.886
46	1.852	1.908	1.855	1.929	1.860	1.951	1.864	1.972	1.869	1.992
47	1.873	2.013	1.878	2.033	1.883	2.053	1.888	2.072	1.893	2.092
48	1.899	2.111	1.904	2.129	1.910	2.148	1.916	2.166	1.922	2.184
49	1.928	2.202	1.935	2.219	1.941	2.237	1.948	2.254	1.954	2.270
50	1.961	2.287	1.968	2.303	1.976	2.319	1.983	2.335	1.990	2.350
51	1.993	2.366	2.006	2.381	2.014	2.395	2.022	2.410	2.030	2.424
52	2.038	2.433	2.047	2.452	2.055	2.466	2.064	2.479	2.073	2.492
53	2.082	2.505	2.091	2.518	2.100	2.530	2.109	2.542	2.119	2.554
54	2.129	2.565	2.138	2.577	2.148	2.589	2.158	2.600	2.168	2.611
55	2.179	2.621	2.189	2.632	2.199	2.642	2.210	2.652	2.221	2.662
56	2.232	2.671	2.243	2.681	2.254	2.690	2.265	2.699	2.276	2.708
57	2.288	2.715	2.299	2.724	2.311	2.733	2.323	2.741	2.335	2.748
58	2.347	2.755	2.359	2.763	2.371	2.770	2.384	2.777	2.396	2.784
59	2.409	2.790	2.422	2.797	2.434	2.803	2.447	2.809	2.460	2.815
60	2.474	2.820	2.487	2.826	2.500	2.831	2.514	2.836	2.527	2.841
61	2.541	2.845	2.555	2.850	2.569	2.854	2.583	2.858	2.597	2.862
62	2.611	2.865	2.625	2.869	2.640	2.872	2.654	2.876	2.669	2.879
63	2.684	2.881	2.699	2.884	2.714	2.887	2.729	2.889	2.744	2.891
64	2.759	2.893	2.774	2.895	2.790	2.896	2.805	2.898	2.821	2.899
65	2.837	2.900	2.853	2.901	2.869	2.902	2.885	2.902	2.901	2.903
66	2.917	2.903	2.933	2.903	2.950	2.903	2.966	2.903	2.983	2.902

Exhibit 8. Example of table for veneer, sawmill, and pulpwood option

NAME OF FIRM OR ORGANIZATION

30 TREES

	HUNDREDS OF POUNDS														
	0			2			4			6			8		
THOUS. OF POUNDS	VENEER (MBF)	SAWMILL (MBF)	PULP (CORDS)	VENEER (MBF)	SAWMILL (MBF)	PULP (CORDS)	VENEER (MBF)	SAWMILL (MBF)	PULP (CORDS)	VENEER (MBF)	SAWMILL (MBF)	PULP (CORDS)	VENEER (MBF)	SAWMILL (MBF)	PULP (CORDS)
30	1.392	0.781	0.0	1.378	0.782	0.0	1.364	0.782	0.0	1.350	0.783	0.0	1.337	0.783	0.0
31	1.324	0.784	0.0	1.311	0.784	0.0	1.299	0.785	0.0	1.287	0.786	0.0	1.275	0.786	0.0
32	1.263	0.787	0.0	1.252	0.787	0.0	1.241	0.787	0.0	1.230	0.788	0.0	1.220	0.788	0.0
33	1.210	0.789	0.0	1.200	0.789	0.0	1.190	0.790	0.0	1.181	0.790	0.0	1.172	0.790	0.0
34	1.163	0.791	0.019	1.155	0.791	0.061	1.147	0.791	0.104	1.139	0.792	0.145	1.131	0.792	0.187
35	1.123	0.792	0.228	1.116	0.793	0.268	1.109	0.793	0.308	1.103	0.793	0.348	1.096	0.793	0.387
36	1.090	0.794	0.426	1.084	0.794	0.464	1.079	0.794	0.502	1.073	0.794	0.540	1.068	0.794	0.577
37	1.063	0.795	0.614	1.058	0.795	0.651	1.054	0.795	0.687	1.049	0.795	0.722	1.045	0.795	0.758
38	1.042	0.795	0.793	1.038	0.796	0.827	1.035	0.796	0.861	1.032	0.796	0.895	1.029	0.796	0.928
39	1.026	0.796	0.961	1.023	0.796	0.994	1.021	0.796	1.026	1.019	0.796	1.058	1.017	0.796	1.090
40	1.016	0.796	1.121	1.014	0.796	1.152	1.013	0.796	1.183	1.012	0.796	1.213	1.011	0.796	1.243
41	1.011	0.796	1.272	1.010	0.796	1.302	1.010	0.796	1.331	1.010	0.796	1.359	1.010	0.796	1.387
42	1.011	0.796	1.415	1.011	0.796	1.443	1.012	0.796	1.470	1.013	0.796	1.497	1.014	0.796	1.524
43	1.016	0.796	1.550	1.017	0.796	1.576	1.019	0.796	1.601	1.021	0.795	1.627	1.023	0.795	1.652
44	1.025	0.795	1.677	1.028	0.795	1.701	1.031	0.795	1.725	1.033	0.795	1.749	1.036	0.795	1.773
45	1.040	0.794	1.796	1.043	0.794	1.819	1.047	0.794	1.841	1.050	0.794	1.864	1.054	0.794	1.886
46	1.058	0.793	1.908	1.062	0.793	1.929	1.067	0.793	1.951	1.071	0.793	1.972	1.076	0.792	1.992
47	1.081	0.792	2.013	1.086	0.792	2.033	1.091	0.792	2.053	1.097	0.791	2.072	1.102	0.791	2.092
48	1.108	0.791	2.111	1.114	0.791	2.129	1.120	0.790	2.148	1.126	0.790	2.166	1.132	0.790	2.184
49	1.139	0.789	2.202	1.146	0.789	2.219	1.152	0.789	2.237	1.159	0.788	2.254	1.167	0.788	2.270
50	1.174	0.788	2.287	1.181	0.787	2.303	1.189	0.787	2.319	1.196	0.786	2.335	1.204	0.786	2.350
51	1.212	0.786	2.366	1.221	0.785	2.381	1.229	0.785	2.395	1.237	0.784	2.410	1.246	0.784	2.424
52	1.255	0.784	2.438	1.263	0.783	2.452	1.272	0.783	2.466	1.282	0.782	2.479	1.291	0.782	2.492
53	1.300	0.781	2.505	1.310	0.781	2.518	1.320	0.780	2.530	1.329	0.780	2.542	1.339	0.780	2.554
54	1.349	0.779	2.566	1.360	0.779	2.577	1.370	0.778	2.589	1.381	0.778	2.600	1.391	0.777	2.611
55	1.402	0.777	2.621	1.413	0.776	2.632	1.424	0.776	2.642	1.435	0.775	2.652	1.446	0.774	2.662
56	1.458	0.774	2.671	1.469	0.773	2.681	1.481	0.773	2.690	1.493	0.772	2.699	1.505	0.772	2.708
57	1.517	0.771	2.716	1.529	0.771	2.724	1.541	0.770	2.733	1.554	0.769	2.741	1.566	0.769	2.748
58	1.579	0.768	2.756	1.591	0.768	2.763	1.604	0.767	2.770	1.617	0.766	2.777	1.630	0.766	2.784
59	1.644	0.765	2.790	1.657	0.764	2.797	1.671	0.764	2.803	1.684	0.763	2.809	1.698	0.763	2.815
60	1.712	0.762	2.820	1.726	0.761	2.826	1.740	0.761	2.831	1.754	0.760	2.836	1.768	0.759	2.841
61	1.782	0.759	2.845	1.797	0.758	2.850	1.812	0.757	2.854	1.826	0.757	2.858	1.841	0.756	2.862
62	1.856	0.755	2.866	1.871	0.754	2.869	1.886	0.754	2.872	1.901	0.753	2.876	1.917	0.752	2.879
63	1.932	0.752	2.881	1.948	0.751	2.884	1.964	0.750	2.887	1.979	0.749	2.889	1.995	0.749	2.891
64	2.011	0.748	2.893	2.027	0.747	2.895	2.044	0.746	2.896	2.060	0.746	2.898	2.076	0.745	2.899
65	2.093	0.744	2.900	2.109	0.743	2.901	2.126	0.743	2.902	2.143	0.742	2.902	2.160	0.741	2.903
66	2.177	0.740	2.903	2.194	0.739	2.903	2.211	0.739	2.903	2.228	0.738	2.903	2.246	0.737	2.902

Output from this program consists of a table (exhibit 9) giving the ID number of each individual check-scale load and the difference between its actual measured product volumes and those calculated by using regression equations developed in generating the previous weight-volume tables. These differences for each product are summed and printed on the table as the "Total Difference." The program also sums the actual volumes of each product contained in the check-scale sample and the total percentage difference is calculated as a percentage of the actual total volume. This percentage gives an indication of the error in the tabular values being checked.

In options 3 and 5 which check both veneer and sawmill volumes, the total veneer difference and the total sawmill difference are added to get a "Total Saw-Log Difference." The total sawmill and veneer volumes of the sample are also combined to get the "Total Saw-Log Volume," and the total saw-log difference is calculated as a percentage of the total volume.

Exhibit 9. Example of CHECK output for pulpwood, veneer, and sawmill option

```
NAME OF FIRM OR ORGANIZATION
                    CHECK SCALES

  DIFFERENCES IN ACTUAL AND CALCULATED DATA

              (ACTUAL-CALCULATED)

          PULP       VENEER      SAWMILL
 ID       CORDS
          (NO)       (MBF)       (MBF)


 435      0.265     -0.744       0.273
 436      0.187     -0.117       0.104
 437     -0.465     -0.107       0.029
 438     -0.533      0.580       0.013
 439     -0.584      0.324       0.017
 440      0.301     -0.214       0.090
 441     -0.600     -0.033       0.070

- - - - - - - - - - - - - - - - - - - - - - -
TOTAL
DIFF.    -1.430     -0.312       0.597

PERCENT
 OF      -11.9       -1.4        14.6
ACTUAL
- - - - - - - - - - - - - - - - - - - - - - -
TOTAL SAWLOG
DIFF.                        0.285
(V.VOL.DIFF.+S.VOL.DIFF.)

TOTAL SAWLOG DIFF.
AS PERCENT OF                1.1
ACTUAL SAWLOG VOL.
```

Similar to WTVOL, CHECK is set up to handle any number of data sets at one time. A blank trailer card must follow each data set if more data sets are to follow. If no more sets follow, the trailer card should contain 9999 in columns 1 through 4. A new name header card, option card, and regression equation coefficients card must head each data set in the program.

Appendix 1 shows definitions of variable names, Appendix 2b includes the program listing for CHECK, Appendix 3b illustrates the deck setup, and Appendix 4 describes input data formats. No subroutines are used in CHECK.

Estimating Weights from Volumes

This program is designed to produce, through regression analysis, tables showing average weight per tree by diameter class and number of usable 16-foot logs. The program is flexible enough to handle any number of form classes, ranging from 65 to 90, any type of log rule (i.e., Scribner, International $\frac{1}{4}$-inch, or Doyle), any volume table giving cubic-foot or board-foot volumes, and any range of diameters for different species.

Five types of data cards are required as input to the program:

1. Name card--same as for WTVOL and CHECK.
2. Option card--includes number of form classes for which tables are desired and the minimum and maximum diameters for which weights are to be estimated in each table.
3. Truckload data cards--same as for WTVOL and CHECK with an additional variable--total saw-log length in linear feet per load.
4. Trailer card--same as for WTVOL and CHECK.
5. Volume cards--volume data by form class, diameter, and number of 16-foot logs (simply volume tables punched into cards).

After the truckload data cards are read, the regression coefficients for determining average total weight per tree and average saw-log weight per tree are determined. They are then applied to the volume data by d.b.h. and number of usable 16-foot logs to produce weight tables by diameter and length for each desired form class and species. In addition to the tabular weights, average total weight per tree, average saw-log weight per tree, average total volume per tree, average number of usable 16-foot logs per tree, percentage variation explained by the regression equations, and their standard errors are computed and are footnoted on each table as illustrated in exhibits 10 and 11.

Exhibit 10. Example of VOLWT average total weight per tree table for form class 78

```
NAME OF FIRM OR ORGANIZATION

FORM CLASS 78                    AVERAGE TOTAL WEIGHT PER TREE*
 TREE                  WEIGHT (M.LBS.) BY NUMBER OF USABLE 16-FOOT LOGS
DIAMETER
(INCHES)        1.0      1.5      2.0      2.5      3.0      3.5      4.0      4.5

   10          0.639    0.915    1.191    1.452    1.712   ------   ------   ------
   11          0.702    0.993    1.285    1.561    1.837   ------   ------   ------
   12          0.756    1.063    1.371    1.662    1.954    2.214    2.482   ------
   13          0.827    1.157    1.495    1.803    2.110    2.386    2.669   ------
   14          0.904    1.266    1.620    1.943    2.266    2.557    2.849   ------
   15          0.998    1.391    1.784    2.130    2.484    2.791    3.106   ------
   16          1.092    1.516    1.940    2.317    2.702    3.041    3.371   ------
   17          1.201    1.664    2.127    2.543    2.959    3.321    3.675   ------
   18          1.310    1.812    2.314    2.769    3.217    3.602    3.979   ------
   19          1.450    1.999    2.548    3.042    3.536    3.945    4.361   ------
   20          1.583    2.186    2.790    3.323    3.856    4.303    4.743    5.136
   21          1.731    2.397    3.062    3.642    4.222    4.709    5.195    5.635
   22          1.887    2.607    3.335    3.970    4.597    5.122    5.647    6.134
   23          2.050    2.841    3.624    4.313    5.002    5.559    6.115    6.648
   24          2.214    3.067    3.920    4.664    5.407    5.995    6.583    7.171
   25          2.409    3.340    4.263    5.077    5.891    6.541    7.191    7.826
   26          2.604    3.605    4.614    5.490    6.366    7.079    7.791    8.480
   27          2.807    3.886    4.972    5.919    6.873    7.632    8.392    9.135
   28          3.002    4.166    5.331    6.355    7.388    8.186    8.984    9.790
   29          3.228    4.486    5.744    6.854    7.964    8.825    9.686   10.570
   30          3.462    4.813    6.165    7.353    8.541    9.464   10.380   11.342
   31          3.711    5.164    6.625    7.915    9.204   10.213   11.214   12.223
   32          3.968    5.523    7.085    8.476    9.867   10.961   12.048   13.103
   33          4.226    5.881    7.545    9.037   10.521   11.678   12.843   13.969
   34          4.475    6.240    8.005    9.583   11.169   12.403   13.638   14.834
   35          4.771    6.661    8.551   10.246   11.940   13.269   14.597   15.887

THE ABOVE TABLE FOR ESTIMATING AVERAGE TOTAL WEIGHT PER TREE WAS DERIVED BY SOLVIN3 THE FOLLOWING---
 *AVERAGE TJTAL WEIGHT PER TREE =   0.02511 +   7.79592 (AVEP. VOL./TREE) +   0.50516 (NO. OF USABLE 16-FOOT LOGS)
    MEAN AVERAGE TOTAL WEIGHT PER TREE =    3.509 (M.LBS.)
    STANDARD DEVIATION OF AVERAGE TOTAL WEIGHT PER TREE =    0.950 (M.LBS.)
    MEAN TOTAL VOLUME PER TREE =    0.257 (M.B.F.)
    STANDARD DEVIATION OF AVERAGE VOLUME PER TREE =    0.091 (M.B.F.)
    VARIATION EXPLAINED BY REGRESSION EQUATION =   88.57 PERCENT
    STANDARD ERROR OF REGRESSION EQUATION =    0.325 (M.LBS.)
    MEAN NO. OF USABLE 16-FOOT LOGS =    2.931 (16-FOOT LOGS)
    STANDARD DEVIATION OF NO. OF USABLE 16-FOOT  LOGS =    0.528 (16-FOOT LOGS)

 *NOTE: AVERAGE VOLUME PER TREE WAS BASED ON DOYLE LOG RULE VOLUMES--
        MESAVAGE AND GIRARD
```

Exhibit 11. Example of VOLWT average saw-log weight per tree table for form class 78

```
NAME OF FIRM OR ORGANIZATION

FORM CLASS 78                    AVERAGE SAWLOG WEIGHT PER TREE*
  TREE               WEIGHT (M.LBS.) BY NUMBER OF USABLE 16-FOOT LOGS
DIAMETER
(INCHES)       1.0      1.5      2.0      2.5      3.0      3.5      4.0      4.5

   10         0.530    0.783    1.036    1.274    1.511   ------   ------   ------
   11         0.591    0.859    1.127    1.380    1.633   ------   ------   ------
   12         0.644    0.928    1.211    1.480    1.748    1.986    2.231   ------
   13         0.713    1.019    1.334    1.617    1.901    2.154    2.414   ------
   14         0.789    1.126    1.456    1.754    2.053    2.321    2.590   ------
   15         0.881    1.248    1.616    1.938    2.267    2.551    2.842   ------
   16         0.973    1.371    1.769    2.121    2.481    2.795    3.101   ------
   17         1.079    1.516    1.952    2.342    2.733    3.070    3.399   ------
   18         1.186    1.661    2.135    2.564    2.985    3.344    3.697   ------
   19         1.324    1.844    2.364    2.831    3.298    3.680    4.071   ------
   20         1.453    2.027    2.601    3.106    3.611    4.031    4.445    4.812
   21         1.599    2.233    2.868    3.419    3.969    4.428    4.887    5.301
   22         1.751    2.439    3.135    3.739    4.336    4.833    5.330    5.789
   23         1.911    2.668    3.417    4.075    4.733    5.260    5.788    6.293
   24         2.072    2.890    3.708    4.419    5.130    5.688    6.246    6.805
   25         2.263    3.157    4.043    4.823    5.603    6.222    6.842    7.446
   26         2.453    3.416    4.387    5.228    6.069    6.749    7.430    8.087
   27         2.652    3.691    4.738    5.648    6.565    7.291    8.017    8.728
   28         2.843    3.966    5.089    6.075    7.069    7.833    8.597    9.370
   29         3.064    4.279    5.494    6.564    7.633    8.459    9.285   10.133
   30         3.293    4.600    5.906    7.052    8.198    9.085    9.964   10.889
   31         3.537    4.943    6.356    7.602    8.847    9.818   10.781   11.751
   32         3.789    5.294    6.807    8.151    9.496   10.551   11.598   12.614
   33         4.041    5.645    7.257    8.701   10.137   11.253   12.376   13.461
   34         4.286    5.997    7.708    9.235   10.771   11.963   13.155   14.309
   35         4.576    6.409    8.242    9.884   11.527   12.810   14.094   15.339

THE ABOVE TABLE FOR ESTIMATING AVERAGE SAWLOG WEIGHT PER TREE WAS DERIVED BY SOLVING THE FOLLOWING---
  *AVERAGE SAWLOG WEIGHT PER TREE =  -0.03726 +   7.63369 (AVER. VOL./TREE) +   0.46018 (NO. OF USABLE 16-FOOT LOGS)
    MEAN AVERAGE SAWLOG WEIGHT PER TREE =     3.274 (M.LBS.)
    STANDARD DEVIATION OF AVERAGE SAWLOG WEIGHT PER TREE =     0.906 (M.LBS.)
    MEAN TOTAL VOLUME PER TREE =     0.257 (M.B.F.)
    STANDARD DEVIATION OF AVERAGE VOLUME PER TREE =     0.091 (M.B.F.)
    VARIATION EXPLAINED BY REGRESSION EQUATION =    90.53 PERCENT
    STANDARD ERROR OF REGRESSION EQUATION =    0.282 (M.LBS.)
    MEAN NO. OF USABLE 16-FOOT LOGS =    2.931 (16-FOOT LOGS)
    STANDARD DEVIATION OF NO. OF USABLE 16-FOOT LOGS =    0.528 (16-FOOT LOGS)

  *NOTE: AVERAGE VOLUME PER TREE WAS BASED ON DOYLE LOG RULE VOLUMES--
         MESAVAGE AND GIRARD
```

VOLWT is as flexible as other programs described here and, in producing multiple sets of tables in a single run, is controlled by the trailer cards similar to those for the other programs. Here, though, the trailer card is used to indicate an end of truckload data and the beginning of volume data in addition to informing the program of an end of data sets. The trailer card should be placed after the truckload data deck as before and should be blank in columns 1 through 4 when additional data sets follow and should contain 9999 in columns 1 through 4 when the data set being read is the last one. When multiple data sets are being read, volume data must follow each data set.

The deck setup for VOLWT is shown in Appendix 3c, input data formats are shown in Appendix 4, and definitions of variable names are shown in Appendix 1. VOLWT also uses subroutines MATINV and MULT as part of its regression analysis.

Subroutines

Subroutines MATINV and MULT are required in both programs WTVOL and VOLWT to perform the regression analysis. MATINV inverts the matrix consisting of sums of squares and sums of products of the independent regression variables. This matrix is given to MATINV by the main programs and MATINV replaces this matrix by its inverse. The inverse matrix and the matrix containing the sums of the dependent variables and the sums of products of the dependent variables times the independent variables are input to MULT. MULT multiplies these two matrices to develop a matrix of regression coefficients which are returned to the main program.

These two subroutines are not hardware dependent and should require no alteration or programer action regardless of the program in which they are used or which option is chosen. No definitions of variable names used in them are included here, but listings for both can be found in Appendices 2d and 2e.

Literature Cited

1. Anonymous
   1973. How to weight scale tree-length logs. For. Farmer 23(11): 13.

2. Fasick, C. A., and S. Guttenberg
   1966. Veneer bolts, saw logs, and pulpwood. For. Prod. J. 16(12): 56-58.

3. ________ G. L. Tyre, and F. M. Riley, Jr.
   1974. Weight-scaling tree-length timber for veneer logs, saw logs, and pulpwood. For. Prod. J. (In press.)

4. ________ G. L. Tyre, and G. D. Screpetis
   1973. Now! You can weight-scale tree-length logs for saw-logs and pulpwood. South. Lumberman 227(2819): 13-16.

5. Freese, F.
   1964. Linear regression methods for forest research. For. Prod. Lab., USDA For. Serv. FPL-17, 136 pp.

6. Guttenberg, S., and C. A. Fasick
   1973. Scaling multiple products by weight. For. Prod. J. 23(5): 34-37.

7. ________ D. L. Fassnacht, and W. C. Siegle
   1960. Weight-scaling southern pine saw logs. USDA For. Serv., South. For. Exp. Stn. Occas. Pap. 177, 6 pp.

8. Page, R. H., and P. J. Bois
   1961. Buying and selling southern yellow pine saw logs by weight. Ga. For. Res. Counc. Rep. 7, 9 pp.

9. Row, C., and C. A. Fasick
   1966. Weight-scaling tables by electronic computer. For. Prod. J. 16(8): 41-45.

10. ________ and S. Guttenberg
    1966. Determining weight-volume relationships for saw logs. For. Prod. J. 16(5): 39-47.

11. Taras, M. A.
    1956. Buying pulpwood by weight: as compared with volume measure. USDA For. Serv. Southeast. For. Exp. Stn. Pap. 74, 11 pp.

Appendix 1

Definitions of Program Variable Names

AMEAN	Array of averages for number of trees per load, total weight per load, board-foot volume per load (sawmill plus veneer volume), saw-log weight per load, board-foot veneer volume per load.
AMNPUL	Mean pulp volume.
AMNPWT	Mean pulp weight.
AMNSML	Mean sawmill volume.
AMSE	Array of mean square errors for the regression equations.
ANLOGS	Number of usable 16-foot logs.
APV	Pulp volume (or weight) per truckload.
ATPV	Total pulp volume (or weight) in all sample truckloads.
ATSLV	Total saw-log volume in all sample truckloads.
ATSV	Total sawmill volume in all sample truckloads.
ATVV	Total veneer volume in all sample truckloads.
B	Array of regression constants and coefficients.
CPV	Calculated pulp volume (or weight).
CSMV	Calculated sawmill volume.
DET	Determinant of the matrix continuing sums, sums of squares and products of the independent variables.
ICOUNT	Line count controlling printer.
ID	Truckload identification number.
IFC	Form class.
IFRAC	Fraction of load weight not in even thousands of pounds.
IO	Code used to select program option which varies according to product raw material.

ITREES	Identifies the number of trees per load to which each table applies. Appears in heading of each table.
ITWT	Truckload weight, in even thousands of pounds, appearing in left-most column of each table.
IW	TWTMIN rounded back to nearest lowest thousands of pounds.
IWTM	Total net load weight.
IX	Do-loop index.
JJ	Diameter class varying from 10-40 inches.
K	Counter used in determining when the number of form classes for which weights have been computed equals NK.
KARRAY	Array of volumes by form class, length, and diameter.
LOGRL	Log rule.
MAXD	Maximum diameter appearing in weight table.
MIND	Minimum diameter appearing in weight table.
NAME	Name of firm or organization.
NCASE	Number of form classes for which tables are to be produced.
NOLDS	Total number of loads.
PPD	Percentage difference in actual pulp volume (or weight) and calculated pulp volume (or weight).
PSLVD	Percentage difference in actual saw-log volume and calculated saw-log volume.
PSVD	Percentage difference in actual sawmill volume and calculated sawmill volume.
PULPWT	Pulpwood weight read from truckload data cards.
PVD	Difference in actual pulp volume (or weight) and calculated pulp volume (or weight) by load.
PVVD	Percentage difference in actual veneer volume and calculated veneer volume.

PWFCTR	Weight per cord factor used in converting pulpwood from pounds to cords.
PWT	Array of pulpwood weights (or volumes) calculated and printed in tables.
REGSS	Regression sum of squares.
RHS	Right-hand side of normal equations.
RSQR	Coefficient of multiple determination.
SAWWT	Array of average saw-log weights.
SCALE	Total truckload volume.
SLVD	Saw-log volume difference per load.
SMLVOL	Sawmill volume.
SOLRHS	Array containing product of B times RHS. Used in calculating sums of squares due to error.
SPWTSQ	Sum of squares of pulp weight.
SPX	Sums, sums of squares and products of the independent variables.
SPYX	Sums, sums of squares and products of independent and dependent variables.
SSE	Sums of squares due to error.
SSMLSQ	Sum of squares of sawmill volume.
SSY	Sum of squares of the dependent variable corrected for the mean.
STD	Standard deviation of variables whose means are defined in AMEAN.
STDPUL	Standard deviation of pulp volume.
STDPWT	Standard deviation of pulp weight.
SUMSML	Sum of sawmill volume.
SVD	Sawmill volume difference per load.
SVOL	Calculated tabular values of sawmill volume.

SWT	Calculated saw-log weight.
TITLE	Name of firm or organization.
TMAX	Maximum number of trees per load observed among sample loads.
TMIN	Minimum number of trees per load observed among sample loads.
TOSAWL	Total saw-log length per truckload.
TOTWT	Total weight per tree.
TPVD	Total pulpwood volume (or weight) difference in the sample.
TREES	Synonymous with ITREES but is in real mode used to calculate tabular values.
TREMAX	Maximum number of trees per load. Used as a delimiter in producing tables.
TREMIN	Minimum number of trees per load. Used as a delimiter in producing tables.
TSLVD	Total saw-log volume difference in the sample.
TSML	Total sawmill volume for all loads.
TSVD	Total sawmill volume difference in the sample.
TVVD	Total veneer volume difference in the sample.
TWT	Net load weight, in even hundreds of pounds, used in calculating tabular values.
TWTI	Synonymous with ITWT but in real mode.
TWTMAX	Maximum net load weight per truckload. Used as a delimiter in producing tables.
TWTMIN	Minimum net load weight per truckload. Used as a delimiter in producing tables.
VAR(1)	The number, one.
VAR(2)	Number of trees per load in WTVOL. Average volume per tree per truckload in VOLWT.
VAR(3)	Total net weight per load in WTVOL. Average saw-log length per tree per truckload in 16-foot logs in VOLWT.

VAR(4)	Square root of total net weight times number of trees per load in WTVOL. Average total weight per tree per truckload in VOLWT.
VAR(5)	Total board-foot volume (sawmill plus veneer) in WTVOL. In VOLWT, the average saw-log weight per tree per truckload.
VAR(6)	Total saw-log weight.
VAR(7)	Total veneer volume.
VVD	Veneer volume difference per load.
VVOL	Calculated tabular veneer volume.
WMAX	Maximum number of trees per load observed among sample loads.
WMIN	Minimum number of trees per load observed among sample loads.
XIFRAC	Synonymous with IFRAC but in real mode.
XIWT	Net load weight rounded to the nearest 200 pounds.
XIWTM	Synonymous with IWTM but in real mode.
XNO	Number of trees or logs per load.
Y	Dependent variables.

Appendix 2a. Listing for WTVOL

```
      DIMENSION NAME(20),VAR(7),SPXY(7,7),SPX(4,4),AMEAN(7),RHS(4,3),REG
     1SS(3),SSE(3),AMSE(3),RSQR(3),PWT(5),SVOL(5),B(4,3),VVOL(5)
      DIMENSION SSY(3),SOLRHS(3),STD(7)
      DOUBLE PRECISION VAR,SPXY,SPX,RHS,VOL,WTS,AMEAN,TREMIN,TREMAX,TWTM
     1IN,TWTMAX,DET,AMNPWT,SSE,AMSE,RSQR,REGSS,PULPWT,PWT,SVOL,TREES,TWT
     2I,SWT,B,SOLRHS,VVOL
      DOUBLE PRECISION SSY,TWT,PWFCTR,STD,STDPWT,SUMPWT,SPWTSQ,STDPVL,SU
     1MSML,SSMLSQ,STDSML,TMIN,TMAX,WMIN,WMAX
    1 DO 2 I=1,7
      DO 2 J=1,7
    2 SPXY(I,J)=0.
      TSML=0
      SUMPWT=0.
      SPWTSQ=0.
      SUMSML=0.
      SSMLSQ=0.
      READ(5,3) (NAME(I),I=1,20)
      READ(5,4)IO,PWFCTR,TREMIN,TREMAX,TWTMIN,TWTMAX
    3 FORMAT(20A4)
    4 FORMAT(I1,F4.3,4F3.0)
C
C     VAR(1) IS ONE.
C     VAR(2) IS THE NUMBER OF TREES PER LOAD.
C     VAR(3) IS TOTAL NET WEIGHT PER LOAD.
C     VAR(4) IS THE SQUARE ROOT OF TOTAL NET WEIGHT X NUMBER OF TREES PER LOAD.
C     VAR(5) IS TOTAL BOARD FOOT VOLUME (SAWMILL + VENEER VOLUME).
C     VAR(6) IS TOTAL SAWLOG WEIGHT.
C     VAR(7) IS TOTAL VENEER VOLUME.
C
    5 READ(5,6)ID,VAR(5),SMLVOL,VAR(7),VAR(3),PULPWT,VAR(2)
    6 FORMAT(I4,3F4.3,2F5.3,F3.0)
C
C   WHERE ID IS EQUAL TO 0 OR 9999, AN END OF SAMPLE DATA HAS BEEN EN-
C   COUNTERED.  WHERE ID IS 0, OTHER DATA SETS WILL FOLLOW.  WHERE ID
C   IS 9999, ALL DATA SETS HAVE BEEN READ.
C
      IF(ID.EQ.0.OR.ID.EQ.9999)GO TO 12
C
C   IF OPTION 1,2, OR 4 IS DESIRED, BOARD-FOOT VOLUMES MAY BE PUNCHED IN
C   THE TOTAL VOLUME FIELD OR IN THE SPECIFIC VOLUME FIELD OR BOTH.  THE
C   FOLLOWING STATEMENTS PLACE VALUES IN FIELDS LEFT BLANK FOR THESE
C   OPTIONS WHEN SPECIFIC AND TOTAL VOLUME FIELDS ARE NOT PUNCHED.
C
      IF(IO.EQ.3.OR.IO.EQ.5)GO TO 7
      IF(VAR(5).EQ.0.)VAR(5)=SMLVOL
      IF(SMLVOL.EQ.0.)SMLVOL=VAR(5)
      IF(VAR(7).EQ.0.)VAR(7)=VAR(5)
C
C   THE FOLLOWING STATEMENTS DETERMINE MINIMUM & MAXIMUM NUMBER OF
C   TREES PER LOAD FROM THE SAMPLE DATA WHEN THESE VALUES ARE NOT
C   SPECIFIED IN THE OPTIONS CARD.
C
    7 IF(TREMIN.NE.0.OR.TREMAX.NE.0)GO TO 8
      IF(SPXY(1,1).EQ.0)TMIN=900.
      IF(SPXY(1,1).EQ.0)TMAX=0.
      IF(VAR(2).LT.TMIN)TMIN=VAR(2)
      IF(VAR(2).GT.TMAX)TMAX=VAR(2)
C
C   THE FOLLOWING STATEMENTS DETERMINE MINIMUM & MAXIMUM LOAD WEIGHTS
C   FROM THE SAMPLE DATA WHEN THESE VALUES ARE NOT SPECIFIED IN THE
C   OPTIONS CARD.
C
    8 IF(TWTMIN.NE.0.OR.TWTMAX.NE.0)GO TO 9
      IF(SPXY(1,1).EQ.0)WMIN=900000.
      IF(SPXY(1,1).EQ.0)WMAX=0.
      IF(VAR(3).LT.WMIN)WMIN=VAR(3)
      IF(VAR(3).GT.WMAX)WMAX=VAR(3)
C
C   VARIABLES USED IN REGRESSION ANALYSIS WHICH ARE NOT READ DIRECTLY
C  ARE DETERMINED BELOW, SUMS AND SUMS OF SQUARES & PRODUCTS ARE ALSO
C   CALCULATED.
C
    9 VAR(1)=1.0
      VAR(4)=(DSQRT(VAR(3)*VAR(2)))
      VAR(6)=VAR(3)-PULPWT
      TSML =TSML + SMLVOL
      IF(IO.EQ.4.OR.IO.EQ.5)GO TO 10
      IF(PULPWT.EQ.0)PULPWT=1
   10 SUMPWT=SUMPWT+PULPWT
      SPWTSQ=SPWTSQ+PULPWT**2
      SUMSML=SUMSML+SMLVOL
      SSMLSQ=SSMLSQ+SMLVOL**2
      DO 11 I=1,7
      DO 11 J=1,7
   11 SPXY(I,J)=SPXY(I,J)+VAR(I)*VAR(J)
      GO TO 5
C
C    SPXY IS SEPARATED INTO SPX (SUMS,SUMS OF SQUARES & PRODUCTS FOR
C    THE INDEPENDENT VARIABLES) AND RHS (THE RIGHT-HAND SIDE OF THE
C    NORMAL EQUATIONS).
C
   12 DO 14 I=1,4
      DO 13 J=1,4
   13 SPX(I,J)=SPXY(I,J)
      RHS(I,1)=SPXY(I,5)
      RHS(I,2)=SPXY(I,6)
   14 RHS(I,3)=SPXY(I,7)
C
C    SUBROUTINE MATINV IS CALLED TO INVERT THE MATRIX SPX.  SUBROUTINE
C    MULT MULTIPLIES THE INVERSE OF SPX AND RHS TO DETERMINE B, THE
C    REGRESSION COEFFICIENTS.
C
      CALL MATINV(SPX,4,DET)
      CALL MULT(SPX,RHS,4,3,4,B)
C
C    STANDARD DEVIATIONS, MEANS, ERROR SUMS OF SQUARES, REGRESSION SUMS OF
C    SQUARES, MEAN SQUARE ERRORS, AND COEFFICIENTS OF VARIATION ARE CALCULATED.
C
      DO 15 I=2,7
      STD(I)=(SPXY(I,I)-((SPXY(1,I)**2)/SPXY(1,1)))/(SPXY(1,1)-1.0)
      STD(I)=DSQRT(STD(I))
   15 AMEAN(I)=SPXY(1,I)/SPXY(1,1)
      AMNPWT=SUMPWT/SPXY(1,1)
      AMNSML = TSML/SPXY(1,1)
      IF(PWFCTR.LE.0.)PWFCTR=1.
      AMNPVL=AMNPWT/PWFCTR
      STDPWT=DSQRT((SPWTSQ-((SUMPWT**2)/SPXY(1,1)))/(SPXY(1,1)-1.0))
      STDPVL=STDPWT/PWFCTR
      STDSML=DSQRT((SSMLSQ-((SUMSML**2)/SPXY(1,1)))/(SPXY(1,1)-1.0))
      DO 19 J=1,3
      SOLRHS(J)=0.
      DO 17 I=1,4
   17 SOLRHS(J)=SOLRHS(J)+B(I,J)*RHS(I,J)
      SSE(J)=SPXY(J+4,J+4)-SOLRHS(J)
      SSY(J)=SPXY(J+4,J+4)-(RHS(1,J)**2/SPXY(1,1))
      REGSS(J)=SSY(J)-SSE(J)
      AMSE(J)=SSE(J)/(SPXY(1,1)-4.0)
      AMSE(J)= (DSQRT (AMSE(J)))
   19 RSQR(J)=REGSS(J)/SSY(J)
      NOLDS=SPXY(1,1)
      IF(TREMIN.EQ.0.)TREMIN=TMIN
      IF(TREMAX.EQ.0.)TREMAX=TMAX
      IF(TWTMIN.EQ.0.)TWTMIN=WMIN
      IF(TWTMAX.EQ.0.)TWTMAX=WMAX
      IW=TWTMIN
      TWTMIN=IW
      GO TO (20,30,40,50,60),IO
C
C    SUMMARY PAGE FOR OPTION 1 IS PRINTED
C
   20 WRITE(6,200)
      WRITE(6,100)(NAME(I),I=1,20)
      WRITE(6,202)NOLDS,AMEAN(2),STD(2),AMNSML,STDSML,AMEAN(6),STD(6)
      WRITE(6,204)(B(I,1),I=1,4)
      WRITE(6,102)RSQR(1),AMSE(1)
C
C    DELIMITERS ARE SET FOR PRODUCING THE TABLES.
C
   21 TREES=TREMIN-1.
   22 TWT=TWTMIN
      TWTI=TWTMIN
      TREES=TREES+1.
      IF(TREES.GT.TREMAX)GO TO 80
      ITREES=TREES
      IF(IO.LE.3)WRITE(6,104)(NAME(I),I=1,20),ITREES
      IF(IO.GT.3)WRITE(6,106)(NAME(I),I=1,20),ITREES
      GO TO (23,33,43,53,63),IO
C
C    TABLE HEADING FOR OPTION 1 IS PRINTED THEN TABULAR VALUES ARE
C    CALCULATED & PRINTED FOR EACH LINE IN THE TABLES.
C
   23 WRITE(6,206)
   24 DO 26 I=1,5
      SVOL(I)=B(1,1)+B(2,1)*TREES+B(3,1)*TWT+B(4,1)*DSQRT(TWT*TREES)
      IF(SVOL(I).LE.0.)SVOL(I)=0.
   26 TWT=TWT+.2
      ITWT=TWTI
      WRITE(6,208)ITWT,(SVOL(I),I=1,5)
      TWTI=TWTI+1.
      IF(TWT.GT.TWTMAX)GO TO 22
      GO TO 24
C
C    SUMMARY PAGE FOR OPTION 2 IS PRINTED
C
   30 WRITE(6,300)
      WRITE(6,100) (NAME(I),I=1,20)
      WRITE(6,302) NOLDS,AMEAN(2),STD(2),AMEAN(7),STD(7),AMEAN(6),STD(6)
      WRITE(6,304) (B(I,3),I=1,4)
      WRITE(6,102) RSQR(3),AMSE(3)
      GO TO 21
C
C    TABLE HEADING FOR OPTION 2 IS PRINTED THEN TABULAR VALUES ARE
C    CALCULATED & PRINTED FOR EACH LINE IN THE TABLES.
C
   33 WRITE(6,306)
   34 DO 36 I=1,5
      VVOL(I)=B(1,3)+B(2,3)*TREES+B(3,3)*TWT+B(4,3)*DSQRT(TWT*TREES)
      IF(VVOL(I).LE.0.) VVOL(I)=0.
   36 TWT=TWT+.2
      ITWT=TWTI
      WRITE(6,208)ITWT,(VVOL(I),I=1,5)
      TWTI=TWTI+1.
      IF(TWT.GT.TWTMAX)GO TO 22
      GO TO 34
C
C    SUMMARY PAGE FOR OPTION 3 IS PRINTED
C
   40 WRITE(6,400)
      WRITE(6,100)(NAME(I),I=1,20)
      WRITE(6,402)NOLDS,AMEAN(2),STD(2),AMNSML,STDSML,AMEAN(7),STD(7),AM
     1EAN(6),STD(6)
      WRITE(6,204)(B(I,1),I=1,4)
      WRITE(6,102)RSQR(1),AMSE(1)
      WRITE(6,404)(B(I,2),I=1,4)
      WRITE(6,102)RSQR(2),AMSE(2)
      WRITE(6,304)(B(I,3),I=1,4)
      WRITE(6,102)RSQR(3),AMSE(3)
      GO TO 21
C
C    TABLE HEADING FOR OPTION 3 IS PRINTED THEN TABULAR VALUES ARE
C    CALCULATED & PRINTED FOR EACH LINE IN THE TABLES.
C
   43 WRITE(6,408)
   44 DO 46 I=1,5
      SVOL(I)=B(1,1)+B(2,1)*TREES+B(3,1)*TWT+B(4,1)*DSQRT(TWT*TREES)
      VVOL(I)=B(1,3)+B(2,3)*TREES+B(3,3)*TWT+B(4,3)*DSQRT(TWT*TREES)
      IF(VVOL(I).LE.0.)VVOL(I)=0.
      IF(SVOL(I).LE.0.)SVOL(I)=0.
      IF(VVOL(I).LT.SVOL(I))GO TO 45
      VVOL(I)=SVOL(I)
      SVOL(I)=0.
      GO TO 46
   45 SVOL(I)=SVOL(I)-VVOL(I)
   46 TWT=TWT+.2
      ITWT=TWTI
      WRITE(6,142)ITWT,VVOL(1),SVOL(1),VVOL(2),SVOL(2),VVOL(3),SVOL(3),V
     1VOL(4),SVOL(4),VVOL(5),SVOL(5)
      TWTI=TWTI+1.
      IF(TWT.GT.TWTMAX)GO TO 22
      GO TO 44
C
C    SUMMARY PAGE FOR OPTION 4 IS PRINTED
```

```
C
   50 WRITE(6,500)
      WRITE(6,100)(NAME(I),I=1,20)
      IF(PWFCTR.LE.1.)GO TO 51
      WRITE(6,502)NOLDS,AMEAN(2),STD(2),AMNPVL,STDPVL,AMNPWT,STDPWT,AMNS
     1ML,STDSML,AMEAN(3),STD(3),AMEAN(6),STD(6)
      GO TO 52
   51 WRITE(6,503)NOLDS,AMEAN(2),STD(2),AMNPWT,STDPWT,AMNSML,STDSML,AMEA
     1N(3),STD(3),AMEAN(6),STD(6)
   52 WRITE(6,504)(B(I,1),I=1,4)
      WRITE(6,102)RSQR(1),AMSE(1)
      WRITE(6,506)(B(I,2),I=1,4)
      WRITE(6,102)RSQR(2),AMSE(2)
      GO TO 21
C
C   TABLE HEADING FOR OPTION 4 IS PRINTED THEN TABULAR VALUES ARE
C   CALCULATED & PRINTED FOR EACH LINE IN THE TABLES.
C
   53 IF(PWFCTR.LE.1.)WRITE(6,510)
      IF(PWFCTR.GT.1.)WRITE(6,508)
   54 DO 56 I=1,5
      SVOL(I)=B(1,1)+B(2,1)*TREES+B(3,1)*TWT+B(4,1)*DSQRT(TWT*TREES)
      SWT=B(1,2)+B(2,2)*TREES+B(3,2)*TWT+B(4,2)*DSQRT(TWT*TREES)
      PWT(I)=(TWT-SWT)/PWFCTR
      IF(SVOL(I).LE.0.)SVOL(I)=0.
      IF(PWT(I).LE.0.)PWT(I)=0.
   56 TWT=TWT+.2
      ITWT=TWTI
      WRITE(6,512)ITWT,SVOL(1),PWT(1),SVOL(2),PWT(2),SVOL(3),PWT(3),SVOL
     1(4),PWT(4),SVOL(5),PWT(5)
      TWTI=TWTI+1.
      IF(TWT.GT.TWTMAX)GO TO 22
      GO TO 54
C
C   SUMMARY PAGE FOR OPTION 5 IS PRINTED
C
   60 WRITE(6,600)
      WRITE(6,100)(NAME(I),I=1,20)
      IF(PWFCTR.LE.1.)GO TO 61
      WRITE(6,602)NOLDS,AMEAN(2),STD(2),AMNPVL,STDPVL,AMNPWT,STDPWT,AMNS
     1ML,STDSML,AMEAN(7),STD(7),AMEAN(3),STD(3),AMEAN(6),STD(6)
      GO TO 62
   61 WRITE(6,603)NOLDS,AMEAN(2),STD(2),AMNPWT,STDPWT,AMNSML,STDSML,AMEA
     1N(7),STD(7),AMEAN(3),STD(3),AMEAN(6),STD(6)
   62 WRITE(6,504)(B(I,1),I=1,4)
      WRITE(6,102)RSQR(1),AMSE(1)
      WRITE(6,506)(B(I,2),I=1,4)
      WRITE(6,102)RSQR(2),AMSE(2)
      WRITE(6,604)(B(I,3),I=1,4)
      WRITE(6,102)RSQR(3),AMSE(3)
      GO TO 21
C
C   TABLE HEADING FOR OPTION 5 IS PRINTED THEN TABULAR VALUES ARE
C   CALCULATED & PRINTED FOR EACH LINE IN THE TABLES.
C
   63 IF(PWFCTR.LE.1.)WRITE(6,607)
      IF(PWFCTR.GT.1.)WRITE(6,606)
   64 DO 66 I=1,5
      SVOL(I)=B(1,1)+B(2,1)*TREES+B(3,1)*TWT+B(4,1)*DSQRT(TWT*TREES)
      SWT=B(1,2)+B(2,2)*TREES+B(3,2)*TWT+B(4,2)*DSQRT(TWT*TREES)
      PWT(I)=(TWT-SWT)/PWFCTR
      VVOL(I)=B(1,3)+B(2,3)*TREES+B(3,3)*TWT+B(4,3)*DSQRT(TWT*TREES)
      IF(VVOL(I).LE.0.)VVOL(I)=0.
      IF(SVOL(I).LE.0.)SVOL(I)=0.
      IF(PWT(I).LE.0.)PWT(I)=0.
      IF(VVOL(I).LT.SVOL(I))GO TO 65
      VVOL(I)=SVOL(I)
      SVOL(I)=0.
      GO TO 66
   65 SVOL(I)=SVOL(I)-VVOL(I)
   66 TWT=TWT+.2
      ITWT=TWTI
      WRITE(6,608)ITWT,VVOL(1),SVOL(1),PWT(1),VVOL(2),SVOL(2),PWT(2),VVO
     1L(3),SVOL(3),PWT(3),VVOL(4),SVOL(4),PWT(4),VVOL(5),SVOL(5),PWT(5)
      TWTI=TWTI+1.
      IF(TWT.GT.TWTMAX)GO TO 22
      GO TO 64
```

Appendix 2a (continued)

```
C
C     IF ID IS 0 GO TO 1 & READ THE NEXT SET OF DATA, OTHERWISE
C     TERMINITATE PROGRAM.
C
   80 IF(ID.EQ.0)GO TO 1
  100 FORMAT(1H0,///,6X,20A4)
  102 FORMAT(1H0,5X,'MULTIPLE R SQUARED = ',F9.4,/,
     1'       STANDARD ERROR = ',F9.4,////)
  104 FORMAT(1H1,5X,20A4,11X,I3,' LOGS')
  106 FORMAT(1H1,5X,20A4,11X,I3,' TREES')
  142 FORMAT(1H ,1X,I3,4X,5(F7.3,4X,F8.3,5X))
  200 FORMAT(1H1,38X,43HWEIGHT SCALING OF LOGS FOR SAWTIMBER VOLUME)
  202 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
     1,'MEAN',22X,'STANDARD DEVIATION',//,
     26X,'NUMBER OF LOGS  = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
     36X,'SAWLOG VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     46X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
  204 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG
     1 VOLUME IS',//,2X,'TOTAL SAWLOG VOLUME = ',F9.4,' + ',F9.4,
     2' (NO OF LOGS) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
     3' (SQRT(TOTAL WEIGHT * NO OF LOGS))')
  206 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,
     1'2',23X,'4',23X,'6',23X,'8',/,'   OF',9X,4(9HSAWTIMBER,15X),
     29HSAWTIMBER,/,' POUNDS',9X,4(5H(MBF),19X),5H(MBF))
  208 FORMAT(1H ,1X,I3,8X,4(F8.3,16X),F8.3)
  300 FORMAT(1H1,41X,40HWEIGHT SCALING OF LOGS FOR VENEER VOLUME)
  302 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
     1,'MEAN',22X,'STANDARD DEVIATION',//,
     26X,'NUMBER OF LOGS  = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
     36X,'VENEER VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     46X,'VENEER WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
  304 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL VENEER
     1 VOLUME IS',//,2X,'VENEER VOLUME = ',F9.4,' + ',F9.4,
     2' (NO OF LOGS) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
     3' (SQRT(TOTAL WEIGHT * NO OF LOGS))')
  306 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,
     1'2',23X,'4',23X,'6',23X,'8',/,'   OF',11X,4(6HVENEER,18X),
     26HVENEER,/,' POUNDS',10X,4(5H(MBF),19X),5H(MBF))
  400 FORMAT(1H1,33X,52HWEIGHT SCALING OF LOGS FOR VENEER AND SAWMILL VO
     1LUME)
  402 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
     1,'MEAN',22X,'STANDARD DEVIATION',//,
     26X,'NUMBER OF LOGS  = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
     36X,'SAWMILL VOLUME  = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     46X,'VENEER VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     56X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
  404 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG
     1 WEIGHT IS',//,2X,'TOTAL SAWLOG WEIGHT = ',F9.4,' + ',F9.4,
     2' (NO OF LOGS) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
     3' (SQRT(TOTAL WEIGHT * NO OF LOGS))')
  408 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,
     1'2',23X,'4',23X,'6',23X,'8',/,'   OF',5X,
     25(18HVENEER      SAWMILL,6X),/,' POUNDS',4X,5(5H(MBF),6X,5H(MBF),8X
     3))
  500 FORMAT(1H1,33X,57HWEIGHT SCALING OF TREES FOR SAWTIMBER AND PULPWO
     1OD VOLUME)
  502 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
     1,'MEAN',22X,'STANDARD DEVIATION',//,
     26X,'NUMBER OF TREES = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
     36X,'PULPWOOD VOLUME = ',F9.4,'  (CORDS)',16X,F9.4,'  (CORDS)',/,
     46X,'PULPWOOD WEIGHT = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
     56X,'SAWLOG VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     66X,'TOTAL WEIGHT    = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
     76X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
  503 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
     1,'MEAN',22X,'STANDARD DEVIATION',//,
     26X,'NUMBER OF TREES = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
     36X,'PULPWOOD WEIGHT = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
     46X,'SAWLOG VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
     56X,'TOTAL WEIGHT    = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
     66X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
  504 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG
     1 VOLUME IS',//,2X,'TOTAL SAWLOG VOLUME = ',F9.4,' + ',F9.4,
     2' (NO OF TREES) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
     3' (SQRT(TOTAL WEIGHT * NO OF TREES))')
  506 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL SAWLOG
     1 WEIGHT IS',//,2X,'TOTAL SAWLOG WEIGHT = ',F9.4,' + ',F9.4,
     2' (NO OF TREES) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
```

Appendix 2a (continued)

```
   3' (SQRT(TOTAL WEIGHT * NO OF TREES))')
508 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,
   1'2',23X,'4',23X,'6',23X,'8',/,'   OF',5X,5(17HSAWTIMBER    PULP,7X
   2),/,' POUNDS',5X,5(17H(MBF)     (CORDS),7X))
510 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,
   1'2',23X,'4',23X,'6',23X,'8',/,'   OF',5X,5(17HSAWTIMBER    PULP,7X
   2),/,' POUNDS',5X,5(17H(MBF)    (POUNDS),7X))
512 FORMAT(1H ,1X,I3,4X,5(F8.3,4X,F7.3,5X))
600 FORMAT(1H1,29X,62HWEIGHT SCALING OF TREES FOR VENEER,SAWMILL AND P
   1ULPWOOD VOLUME)
602 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
   1,'MEAN',22X,'STANDARD DEVIATION',//,
   26X,'NUMBER OF TREES = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
   36X,'PULPWOOD VOLUME = ',F9.4,'  (CORDS)',16X,F9.4,'  (CORDS)',/,
   46X,'PULPWOOD WEIGHT = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
   56X,'SAWMILL VOLUME  = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
   66X,'VENEER VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
   76X,'TOTAL WEIGHT    = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
   86X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
603 FORMAT(1H0,/////,6X,'NUMBER OF LOADS',6X,'= ',I4,'  (NO.)',///,27X
   1,'MEAN',22X,'STANDARD DEVIATION',//,
   26X,'NUMBER OF TREES = ',F9.4,'  (NO.)',18X,F9.4,'  (NO.)',/,
   36X,'PULPWOOD WEIGHT = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
   46X,'SAWMILL VOLUME  = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
   56X,'VENEER VOLUME   = ',F9.4,'  (MBF)',18X,F9.4,'  (MBF)',/,
   66X,'TOTAL WEIGHT    = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)',/,
   76X,'SAWLOG WEIGHT   = ',F9.4,'  (MLBS)',17X,F9.4,'  (MLBS)')
604 FORMAT(1H0,5X,'THE REGRESSION EQUATION FOR ESTIMATING TOTAL VENEER
   1 VOLUME IS',//,2X,'VENEER VOLUME = ',F9.4,'+ ',F9.4,
   2' (NO OF TREES) + ',F9.4,' (TOTAL WEIGHT) + ',F9.4,
   3' (SQRT(TOTAL WEIGHT * NO OF TREES))')
606 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,'2',
   123X,'4',23X,'6',23X,'8',/,'   OF',4X,5(24HVENEER SAWMILL  PULP
   2),/,' POUNDS',3X,5(24H(MBF)   (MBF) (CORDS)   ))
607 FORMAT(1H ,59X,'HUNDREDS OF POUNDS',/,' THOUS.',11X,'0',23X,'2',
   123X,'4',23X,'6',23X,'8',/,'   OF',4X,5(24HVENEER SAWMILL  PULP
   2),/,' POUNDS',3X,5(24H(MBF)  (MBF) (POUNDS)   ))
608 FORMAT(1H ,2X,I3,2X,5(F7.3,F8.3,F7.3,2X))
    STOP
    END
```

Appendix 2b. Listing for CHECK

```
      DIMENSION NAME(20),B(3,4),Y(3),VAR(7)
    1 ICOUNT=0
      ATVV=0.
      ATSV=0.
      TVVD=0.
      ATPV=0.
      TSVD=0.
      TPVD=0.
      TSLVD=0.
      ATSLV=0.
      READ(5,3)(NAME(I),I=1,20)
    3 FORMAT(20A4)
      READ(5,5)IO,PWFCTR
    5 FORMAT(I1,F4.3)
      IF(IO.EQ.1)WRITE(6,7)(NAME(I),I=1,20)
      IF(IO.EQ.2)WRITE(6,8)(NAME(I),I=1,20)
      IF(IO.EQ.3)WRITE(6,9)(NAME(I),I=1,20)
      IF(IO.EQ.4.AND.PWFCTR.EQ.0)WRITE(6,10)(NAME(I),I=1,20)
      IF(IO.EQ.4.AND.PWFCTR.NE.0)WRITE(6,11)(NAME(I),I=1,20)
      IF(IO.EQ.5.AND.PWFCTR.EQ.0)WRITE(6,12)(NAME(I),I=1,20)
      IF(IO.EQ.5.AND.PWFCTR.NE.0)WRITE(6,13)(NAME(I),I=1,20)
    7 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',//,29X,'SAWLOG',/,18X,
     3'ID',9X,'(MBF)',//)
    8 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',//,29X,'VENEER',/,18X,
     3'ID',9X,'(MBF)',//)
    9 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',//,20X,'VENEER',7X,'SAWMILL',
     3/,13X,'ID',5X,'(MBF)',8X,'(MBF)',//)
   10 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',// 22X,'PJLP',7X,'SAWLOG',
     3/,13X,'ID',6X,'POUNDS',/,21X,'(MLBS)',7X,'(MBF)',//)
   11 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',// 22X,'PJLP',7X,'SAWLOG',
     3/,13X,'ID',7X,'CORDS',/,22X,'(NO)',7X,'(MBF)',//)
   12 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',//,10X,'PJLP',6X,'VENEEP',
     35X,'SAWMILL',/,2X,'ID',5X,'POUNDS',/,9X,'(MLBS)',
     46X,'(MBF)',6X,'(MBF)',//)
   13 FORMAT(1H1,20A4,/,19X,'CHECK SCALES',//,3X,
     1'DIFFERENCES IN ACTUAL AND CALCULATED DATA',//,
     215X,'(ACTUAL-CALCULATED)',//,10X,'PULP',6X,'VENEER',
     35X,'SAWMILL',/,2X,'ID',6X,'CORDS',/,10X,'(NO)',
     46X,'(MBF)',6X,'(MBF)',//)
   14 IX=1
      IF(IO.EQ.3)IX=2
      IF(IO.EQ.4)IX=2
      IF(IO.EQ.5)IX=3
      DO 17 I=1,IX
      READ(5,15)(B(I,J),J=1,4)
   15 FORMAT(4F9.4)
   17 CONTINUE
C
C     VAR(5) - TOTAL LOAD SCALE (ANY SCALE)
C     VAR(7) - VENEER VOLUME (ANY SCALE)
C     VAR(3) - TOTAL NET LOAD WEIGHT (M.LBS.)
C     VAR(2) - NUMBER OF TREES OR LOGS ON LOAD
C
   19 READ(5,20)IO,VAR(5),SMLVOL,VAR(7),VAR(3),PULPWT,VAR(2)
   20 FORMAT(I4,3F4.3,2F5.3,F3.0)
      IF(IO.EQ.3.OR.IO.EQ.5)GO TO 21
      IF(SMLVOL.EQ.0)SMLVOL=VAR(5)
      IF(VAR(5).EQ.0)VAR(5)=SMLVOL
      IF(VAR(7).EQ.0)VAR(7)=VAR(5)
   21 IF(ID.EQ.0.OR.ID.EQ.9999)GO TO 22
      GO TO 23
   22 IF(IO.EQ.1)GO TO 32
      IF(IO.EQ.2)GO TO 37
      IF(IO.EQ.3)GO TO 45
      IF(IO.EQ.4)GO TO 55
      IF(IO.EQ.5)GO TO 65
   23 ICOUNT=ICOUNT+1
C
C   THE FOLLOWING 12 STATEMENTS ROUND THE TRUCKLOAD
C   WEIGHT TO THE NEAREST EVEN HUNDRED POUNDS.
C
      IWTM=VAR(3)
      IFRAC=(VAR(3)-FLOAT(IWTM))*10.0
      DO 24 K=1,9,2
      IF(IFRAC.EQ.K)IFRAC=IFRAC+1
   24 CONTINUE
      IF(IFRAC.NE.10)GO TO 25
      IFRAC=0
      IWTM=IWTM+1
   25 XIWTM=IWTM
      XIFRAC=IFRAC
      XIWT=XIWTM+(XIFRAC/10.)
      XNO=VAR(2)
      DO 27 I=1,IX
C
C   THIS REGRESSION EQUATION CALCULATES THE SAME
C   VALUES AS PRODUCED IN THE WTVOL TABLES.
C
      Y(I)=B(I,1)+B(I,2)*XNO+B(I,3)*XIWT+B(I,4)*SQRT(XNO*XIWT)
      IF(Y(I).LE.0)Y(I)=0.
   27 CONTINUE
      IF(IO.EQ.1)GO TO 29
      IF(IO.EQ.2)GO TO 34
      IF(IO.EQ.3)GO TO 39
      IF(IO.EQ.4)GO TO 49
      IF(IO.EQ.5)GO TO 59
C
C   STATEMENT #29 THRU 'GO TO 1' IS OPTION NUMBER 1
C
   29 SLVD=VAR(5)-Y(1)
      IF(ICOUNT.EQ.40)WRITE(6,30)
      IF(ICOUNT.EQ.82)WRITE(6,30)
      IF(ICOUNT.EQ.124)WRITE(6,30)
      IF(ICOUNT.EQ.166)WRITE(6,30)
   30 FORMAT(1H1)
      WRITE(6,31)ID,SLVD
   31 FORMAT(1H ,15X,I4,9X,F6.3)
      TSLVD=TSLVD+SLVD
      ATSLV=ATSLV+VAR(5)
      GO TO 19
   32 PSLVD=(TSLVD/ATSLV)*100.
      WRITE(6,33)TSLVD,PSLVD
   33 FORMAT(1H ,/,' - - - - - - - - - - - - - - - - - - - - -',
     1/,17X,'TOTAL',/,17X,'DIFF.',6X,F7.3,//,17X,'PERCENT',/,
     218X,'OF',9X,F5.1,/,17X,'ACTUAL')
      IF(ID.EQ.9999)GO TO 69
      GO TO 1
C
C   STATEMENT #34 THRU 'GO TO 1' IS OPTION NUMBER 2
C
   34 VVD=VAR(7)-Y(1)
      IF(ICOUNT.EQ.40)WRITE(6,35)
      IF(ICOUNT.EQ.82)WRITE(6,35)
      IF(ICOUNT.EQ.124)WRITE(6,35)
      IF(ICOUNT.EQ.166)WRITE(6,35)
```

```
    35 FORMAT(1H1)
       WRITE(6,36)ID,VVD
    36 FORMAT(1H ,15X,I4,9X,F6.3)
       TVVD=TVVD+VVD
       ATVV=ATVV+VAR(7)
       GO TO 19
    37 PVVD=(TVVD/ATVV)*100.
       WRITE(6,38)TVVD,PVVD
    38 FORMAT(1H ,/,' - - - - - - - - - - - - - - - - - - - - - - - -',
      1/,17X,'TOTAL',/,17X,'DIFF.',6X,F7.3,//,17X,'PERCENT',/,
      218X,'OF',9X,F5.1,/,17X,'ACTUAL')
       IF(ID.EQ.9999)GO TO 69
       GO TO 1
C
C    STATEMENT #39 THRU 'GO TO 1' IS OPTION NUMBER 3
C
    39 VVD=VAR(7)-Y(2)
       CSMV=Y(1)-Y(2)
       SVD=SMLVOL-CSMV
       IF(ICOUNT.EQ.32)WRITE(6,41)
       IF(ICOUNT.EQ.74)WRITE(6,41)
       IF(ICOUNT.EQ.116)WRITE(6,41)
       IF(ICOUNT.EQ.158)WRITE(6,41)
    41 FORMAT(1H1)
       WRITE(6,43)ID,VVD,SVD
    43 FORMAT(1H ,10X,I4,5X,F6.3,7X,F6.3)
       TVVD=TVVD+VVD
       TSVD=TSVD+SVD
       ATSV=ATSV+SMLVOL
       ATVV=ATVV+VAR(7)
       GO TO 19
    45 TSLVD=TVVD+TSVD
       ATSLV=ATSV+ATVV
       PSVD=(TSVD/ATSV)*100.
       PVVD=(TVVD/ATVV)*100.
       PSLVD=(TSLVD/ATSLV)*100.
       WRITE(6,47)TVVD,TSVD,PVVD,PSVD,TSLVD,PSLVD
    47 FORMAT(1H ,/,'- - - - - - - - - - - - - - - - - - - - - - - -',/,
      110X,'TOTAL',/,10X,'DIFF.',4X,F7.3,6X,F7.3,//,10X,
      2'PERCENT',/,11X,'OF',7X,F5.1,8X,F5.1,/,10X,'ACTUAL',/,
      3'- - - - - - - - - - - - - - - - - - - - - - - - -',/,10X,
      4'TOTAL SAWLOG',/,10X,'DIFF.',12X,F7.3,/,10X,
      5'(V.VOL.DIFF.+S.VOL.DIFF.)',//,10X,'TOTAL SAWLOG DIFF',/,
      610X,'AS PERCENT OF',5X,F5.1,/,10X,'ACTUAL SAWLOG VOL.',//)
       IF(ID.EQ.9999)GO TO 69
       GO TO 1
C
C    STATEMENT #49 THRU 'GO TO 1' IS OPTION NUMBER 4
C
    49 IF(PWFCTR.EQ.0)GO TO 50
       CPV=(XIWT-Y(2))/PWFCTR
       APV=PULPWT/PWFCTR
       PVD=APV-CPV
       GO TO 51
    50 CPV=(XIWT-Y(2))
       APV=PULPWT
       PVD=APV-CPV
    51 SLVD=VAR(5)-Y(1)
       IF(ICOUNT.EQ.40)WRITE(6,52)
       IF(ICOUNT.EQ.82)WRITE(6,52)
       IF(ICOUNT.EQ.124)WRITE(6,52)
       IF(ICOUNT.EQ.166)WRITE(6,52)
    52 FORMAT(1H1)
       WRITE(6,53)ID,PVD,SLVD
    53 FORMAT(1H ,10X,I4,6X,F6.3,6X,F6.3)
       TPVD=TPVD+PVD
       TSLVD=TSLVD+SLVD
       ATPV=ATPV+APV
       ATSLV=ATSLV+VAR(5)
       GO TO 19
      55 PPD=(TPVD/ATPV)*100.
         PSLVD=(TSLVD/ATSLV)*100.
         WRITE(6,57)TPVD,TSLVD,PPD,PSLVD
      57 FORMAT(1H ,/,' - - - - - - - - - - - - - - - - - - - - - - -',/,
        112X,'TOTAL',/,12X,'DIFF.',3X,F7.3,5X,F7.3,//,12X,'PERCENT',
        2/,13X,'OF',6X,F5.1,7X,F5.1,/,12X,'ACTUAL')
         IF(ID.EQ.9999)GO TO 69
         GO TO 1
C
C     STATEMENT #59 THRU 'GO TO 1' IS OPTION NUMBER 5
C
      59 IF(PWFCTR.EQ.0)GO TO 60
         CPV=(XIWT-Y(2))/PWFCTR
         APV=PULPWT/PWFCTR
         PVD=APV-CPV
         GO TO 61
      60 CPV=(XIWT-Y(2))
         APV=PULPWT
         PVD=APV-CPV
      61 VVD=VAR(7)-Y(3)
         CSMV=Y(1)-Y(3)
         SVD=SMLVOL-CSMV
         IF(ICOUNT.EQ.32)WRITE(6,62)
         IF(ICOUNT.EQ.74)WRITE(6,62)
         IF(ICOUNT.EQ.116)WRITE(6,62)
         IF(ICOUNT.EQ.158)WRITE(6,62)
      62 FORMAT(1H1)
         WRITE(6,63)ID,PVD,VVD,SVD
      63 FORMAT(1H ,I4,4X,F6.3,5X,F6.3,5X,F6.3)
         TVVD=TVVD+VVD
         TSVD=TSVD+SVD
         TPVD=TPVD+PVD
         ATSV=ATSV+SMLVOL
         ATVV=ATVV+VAR(7)
         ATPV=ATPV+APV
         GO TO 19
      65 TSLVD=TVVD+TSVD
         ATSLV=ATSV+ATVV
         PSLVD=(TSLVD/ATSLV)*100.
         PPD=(TPVD/ATPV)*100.
         PSVD=(TSVD/ATSV)*100.
         PVVD=(TVVD/ATVV)*100.
         WRITE(6,67)TPVD,TVVD,TSVD,PPD,PVVD,PSVD,TSLVD,PSLVD
      67 FORMAT(1H ,/,' - - - - - - - - - - - - - - - - - - - - - - - -',
        1/,' TOTAL',/,' DIFF.',2X,F7.3,4X,F7.3,4X,F7.3,//,' PERCENT',/,
        22X,'OF',5X,F5.1,6X,F5.1,6X,F5.1,/,' ACTUAL',/,
        3' - - - - - - - - - - - - - - - - - - - - - - - - - -',/,' TOTAL SAWLOG',
        4/,' DIFF.',20X,F7.3,/,' (V.VOL.DIFF.+S.VOL.DIFF.)',//,
        5' TOTAL SAWLOG DIFF.',/,' AS PERCENT OF',12X,F5.1,/,
        6' ACTUAL SAWLOG VOL.')
         IF(ID.EQ.9999)GO TO 69
         GO TO 1
C
C     CHECK SCALE DATA ARE CHECKED AGAINST
C     PREVIOUS MONTH'S WEIGHT/VOLUME TABLES
C
      69 STOP
         END
```

Appendix 2c. Listing for VOLWT

```
      DIMENSION KARRAY(31,11),TOTWT(31,11),SAWWT(31,11),B(3,2),RSQR(2),A
     2MSE(2),TITLE(20),ID(31),SPXY(5,5),VAR(5),SPX(3,3),RHS(3,2),AMEAN(5
     3),SOLRHS(2),SSE(2),SSY(2),REGSS(2),STD(5)
      DOUBLE PRECISION TOTWT,SAWWT,RSQR,AMSE,B,VAR,SPXY,SPX,RHS,AMEAN,SO
     2LRHS,SSE,SSY,REGSS,DET,STD,ANLOGS,SCALE,SAWVOL,VENVOL,TOTWHT,PULPW
     3T,ATREES,TOSAWL
      DO 1 I=1,5
      DO 1 J=1,5
    1 SPXY(I,J)=0.
      DO 2 I=1,5
      VAR(I)=0.
    2 CONTINUE
      DO 4 I=1,3
      DO 3 J=1,3
      SPX(I,J)=0.
    3 CONTINUE
    4 CONTINUE
      DO 8 I=1,2
      SOLRHS(I)=0.
    8 CONTINUE
      DO 9 I=1,2
      SSE(I)=0.
      SSY(I)=0.
      REGSS(I)=0.
    9 CONTINUE
      DO 10 I=1,5
      STD(I)=0.
   10 CONTINUE
      K=0
      ND=0
C
C     AT THIS POINT A SINGLE CARD IS READ WHICH DEFINES THE NUMBER OF FORM
C     CLASSES FOR WHICH TABLES ARE TO BE COMPUTED (NCASE), THE KIND OF LOG
C     RULE TABLES USED (LOGRL), AND THE MINIMUM AND MAXIMUM DIAMETERS FOR
C     WHICH THE RANGE OF DIAMETERS IS TO BE DEFINED (MIND AND MAXD).
C
   11 READ(5,12)NCASE,LOGRL,MIND,MAXD
   12 FORMAT(I3,I1,2I3)
      ND=(MAXD-MIND)+1
C
C     NEXT A TITLE CARD IS READ INDICATING THE NAME OF THE ORGANIZATION FOR
C     WHICH THE TABLES ARE BEING COMPUTED.
C
      READ(5,13)(TITLE(I),I=1,20)
   13 FORMAT(20A4)
C
C     AT THIS POINT IN THE PROGRAM ALL TRUCK LOAD DATA IS READ INTO THE COM-
C     PUTER AND VAR(1) THROUGH VAR(5) ARE DEFINED.  THESE VARIABLES REPRESENT
C     1.0, AVERAGE VOLUME PER TREE, AVERAGE SAWLOG LENGTH PER TREE, AVERAGE
C     WEIGHT PER TREE, AND AVERAGE SAWLOG WEIGHT PER TREE, RESPECTIVELY.
C
   14 READ(5,15)IDNO,SCALE,SAWVOL,VENVOL,TOTWHT,PULPWT,ATREES,TOSAWL
   15 FORMAT(1X,I3,3F4.3,2F5.3,F3.0,F5.0)
      IF(SCALE.EQ.0.) SCALE=SAWVOL
      IF(IDNO.EQ.0.OR.IDNO.EQ.999) GO TO 17
      VAR(1)=1.0D0
      VAR(2)=SCALE/ATREES
      VAR(3)=((TOSAWL)/ATREES)/16.D0
      VAR(4)=TOTWHT/ATREES
      VAR(5)=(TOTWHT-PULPWT)/ATREES
      DO 16 I=1,5
      DO 16 J=1,5
   16 SPXY(I,J)=SPXY(I,J)+VAR(I)*VAR(J)
      GO TO 14
   17 DO 18 I=1,5
      DO 18 J=1,5
   18 IF(SPXY(I,J).EQ.0) SPXY(I,J)=1.
      DO 20 I=1,3
      DO 19 J=1,3
   19 SPX(I,J)=SPXY(I,J)
      RHS(I,1)=SPXY(I,4)
   20 RHS(I,2)=SPXY(I,5)
      CALL MATINV(SPX,3,DET)
      CALL MULT(SPX,RHS,3,2,3,B)
      DO 21 I=2,5
      STD(I)=(SPXY(I,I)-((SPXY(1,I)**2)/SPXY(1,1)))/(SPXY(1,1)-1.0D0)
      STD(I)=DSQRT(STD(I))
   21 AMEAN(I)=SPXY(1,I)/SPXY(1,1)
      DO 23 J=1,2
      SOLRHS(J)=0.
      DO 22 I=1,3
   22 SOLRHS(J)=SOLRHS(J)+B(I,J)*RHS(I,J)
      SSE(J)=SPXY(J+3,J+3)-SOLRHS(J)
      SSY(J)=SPXY(J+3,J+3)-(RHS(1,J)**2/SPXY(1,1))
      REGSS(J)=SSY(J)-SSE(J)
      AMSE(J)=SSE(J)/(SPXY(1,1)-2.0D0)
      AMSE(J)=DABS(AMSE(J))
      AMSE(J)=DSQRT(AMSE(J))
      RSQR(J)=REGSS(J)/SSY(J)
   23 RSQR(J)=RSQR(J)*100.D0
   24 K=K+1
C
C  ONE SET OF FORM CLASS VOLUMES ARE READ AT A TIME AND ALL TOTAL WEIGHT
C  AND SAWLOG WEIGHT CALCULATIONS ARE MADE BEFORE ANOTHER FORM CLASS IS
C  READ IN.
C
      DO 26 I=1,ND
      READ(5,25)(KARRAY(I,J),J=1,11),ID(I)
   25 FORMAT(11I5,21X,I4)
   26 CONTINUE
      DO 27 I=1,ND
      ANLOGS=.5
      DO 27 J=1,8
      ANLOGS=ANLOGS+.5
      TOTWT(I,J)=B(1,1)+B(2,1)*((DFLOAT(KARRAY(I,J)))/1000.D0)+(B(3,1)*A
     2NLOGS)
      SAWWT(I,J)=B(1,2)+B(2,2)*((DFLOAT(KARRAY(I,J)))/1000.D0)+(B(3,2)*A
     2NLOGS)
   27 CONTINUE
C
C  THIS SET OF STATEMENTS DETERMINES THE FORM CLASS FOR WHICH THE CAL-
C  CULATIONS HAVE BEEN MADE FROM THE ID PREVIOUSLY READ IN.
C
      DO 28 I=6510,9010,100
      IF(ID(1).EQ.(I)) IFC=((I)-10)/100
   28 CONTINUE
C
C  FROM THIS POINT ON THE PROGRAM DETERMINES AND PRINTS OUT THE APPROPRIATE
C  TITLE HEADINGS, FORM CLASS HEADINGS, AND WEIGHT CALCULATIONS.
C
      DO 53 N=1,2
      WRITE(6,29)(TITLE(I),I=1,20)
   29 FORMAT(1H1,2X,20A4)
      IF(N.EQ.2) GO TO 31
      WRITE(6,30)IFC
   30 FORMAT(1H0,2X,'FORM CLASS ',I2,17X,'AVERAGE TOTAL WEIGHT PER TREE*
     2')
      GO TO 33
   31 WRITE(6,32)IFC
   32 FORMAT(1H0,2X,'FORM CLASS ',I2,17X,'AVERAGE SAWLOG WEIGHT PER TREE
     2*')
   33 WRITE(6,34)
   34 FORMAT(1H ,3X,'TREE',17X,'WEIGHT (M.LBS.) BY NUMBER OF USABLE 16-F
     2OOT LOGS',28X/2X,'DIAMETER',90X/2X,'(INCHES)',8X,'1.0       1.5
     3    2.0        2.5        3.0        3.5        4.0        4.5
     4'/)
      IF(N.EQ.2) GO TO 47
      JJ=9
      DO 38 I=1,ND
      JJ=JJ+1
      IF(JJ.LE.11)WRITE(6,35)JJ,(TOTWT(I,J),J=1,5)
   35 FORMAT(1H ,3X,I3,9X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,4X,'-----
     2-',4X,'------',4X,'------',6X)
      IF(JJ.GT.11.AND.JJ.LT.20)WRITE(6,36)JJ,(TOTWT(I,J),J=1,7)
   36 FORMAT(1H ,3X,I3,9X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3
     2X,F7.3,4X,'------',6X)
      IF(JJ.GT.19.AND.JJ.LE.MAXD)WRITE(6,37)JJ,(TOTWT(I,J),J=1,8)
   37 FORMAT(1H ,3X,I3,9X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3
     2X,F7.3,3X,F7.3,6X)
   38 CONTINUE
      WRITE(6,39)B(1,1),B(2,1),B(3,1),AMEAN(4),STD(4),AMEAN(2),STD(2),RS
```

Appendix 2c (continued)

```
     2QR(1),AMSE(1),AMEAN(3),STD(3)
   39 FORMAT(1H0,'THE ABOVE TABLE FOR ESTIMATING AVERAGE TOTAL WEIGHT PE
     2R TREE WAS DERIVED BY SOLVING THE FOLLOWING---'/3X,'*AVERAGE TOTAL
     3 WEIGHT PER TREE = ',F9.5,' + ',F9.5,' (AVER. VOL./TREE)',' + ',F9
     4.5,' (NO. OF USABLE 16-FOOT LOGS)'/6X,'MEAN AVERAGE TOTAL WEIGHT P
     5ER TREE = ',F8.3,' (M.LBS.)'/6X,'STANDARD DEVIATION OF AVERAGE TOT
     6AL WEIGHT PER TREE = ',F8.3,' (M.LBS.)'/6X,'MEAN TOTAL VOLUME PER
     7TREE = ',F8.3,' (M.B.F.)'/6X,'STANDARD DEVIATION OF AVERAGE VOLUME
     8 PER TREE = ',F8.3,' (M.B.F.)'/6X,'VARIATION EXPLAINED BY REGRESSI
     9ON EQUATION = ',F7.2,' PERCENT'/6X,'STANDARD ERROR OF REGRESSION E
     1QUATION = ',F8.3,' (M.LBS.)'/6X,'MEAN NO. OF USABLE 16-FOOT LOGS =
     2 ',F8.3,' (16-FOOT LOGS)'/6X,'STANDARD DEVIATION OF NO. OF USABLE
     316-FOOT  LOGS = ',F8.3,' (16-FOOT LOGS)')
      IF(LOGRL.NE.1) GO TO 41
      WRITE(6,40)
   40 FORMAT(1H0,2X,'*NOTE: AVERAGE VOLUME PER TREE WAS BASED ON SCRIBNE
     2R LOG RULE VOLUMES--'/10X,'MESAVAGE AND GIRARD')
      GO TO 53
   41 IF(LOGRL.NE.2) GO TO 43
      WRITE(6,42)
   42 FORMAT(1H0,2X,'*NOTE: AVERAGE VOLUME PER TREE WAS BASED ON INTERNA
     2TIONAL 1/4-INCH LOG RULE VOLUMES--'/10X,'MESAVAGE AND GIRARD')
      GO TO 53
   43 IF(LOGRL.NE.3) GO TO 45
      WRITE(6,44)
   44 FORMAT(1H0,2X,'*NOTE: AVERAGE VOLUME PER TREE WAS BASED ON DOYLE L
     2OG RULE VOLUMES--'/10X,'MESAVAGE AND GIRARD')
      GO TO 53
   45 IF(LOGRL.EQ.4)WRITE(6,46)
   46 FORMAT(1H0,2X,'*NOTE: AVERAGE VOLUME PER TREE WAS BASED ON LOCAL V
     2OLUME TABLES')
      GO TO 53
   47 JJ=9
      DO 48 I=1,ND
      JJ=JJ+1
      IF(JJ.LE.11)WRITE(6,35)JJ,(SAWWT(I,J),J=1,5)
      IF(JJ.GT.11.AND.JJ.LT.20)WRITE(6,36)JJ,(SAWWT(I,J),J=1,7)
      IF(JJ.GT.19.AND.JJ.LE.MAXD)WRITE(6,37)JJ,(SAWWT(I,J),J=1,8)
   48 CONTINUE
      WRITE(6,49)B(1,2),B(2,2),B(3,2),AMEAN(5),STD(5),AMEAN(2),STD(2),RS
     2QR(2),AMSE(2),AMEAN(3),STD(3)
   49 FORMAT(1H0,'THE ABOVE TABLE FOR ESTIMATING AVERAGE SAWLOG WEIGHT P
     2ER TREE WAS DERIVED BY SOLVING THE FOLLOWING---'/3X,'*AVERAGE SAWL
     3OG WEIGHT PER TREE = ',F9.5,' + ',F9.5,' (AVER. VOL./TREE)',' + ',
     4F9.5,' (NO. OF USABLE 16-FOOT LOGS)'/6X,'MEAN AVERAGE SAWLOG WEIGH
     5T PER TREE = ',F8.3,' (M.LBS.)'/6X,'STANDARD DEVIATION OF AVERAGE
     6SAWLOG WEIGHT PER TREE = ',F8.3,' (M.LBS.)'/6X,'MEAN TOTAL VOLUME
     7PER TREE = ',F8.3,' (M.B.F.)'/6X,'STANDARD DEVIATION OF AVERAGE VO
     8LUME PER TREE = ',F8.3,' (M.B.F.)'/6X,'VARIATION EXPLAINED BY REGR
     9ESSION EQUATION = ',F7.2,' PERCENT'/6X,'STANDARD ERROR OF REGRESSI
     1ON EQUATION = ',F8.3,' (M.LBS.)'/6X,'MEAN NO. OF USABLE 16-FOOT LO
     2GS = ',F8.3,' (16-FOOT LOGS)'/6X,'STANDARD DEVIATION OF NO. OF USA
     3BLE 16-FOOT LOGS = ',F8.3,' (16-FOOT LOGS)')
      IF(LOGRL.NE.1) GO TO 50
      WRITE(6,40)
      GO TO 53
   50 IF(LOGRL.NE.2) GO TO 51
      WRITE(6,42)
      GO TO 53
   51 IF(LOGRL.NE.3) GO TO 52
      WRITE(6,44)
      GO TO 53
   52 IF(LOGRL.EQ.4)WRITE(6,46)
   53 CONTINUE
      IF(K.EQ.NCASE) GO TO 54
      GO TO 24
   54 K=0
      IF(IDNO.NE.999) GO TO 11
      STOP
      END
```

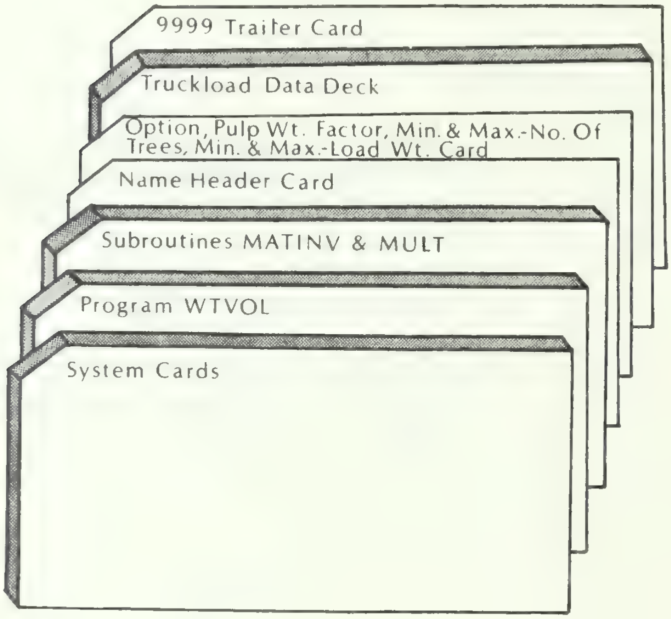
Appendix 2d. Listing for MATINV

```
      SUBROUTINE MATINV(A,N,DET)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION IPIVOT(20),INDEX(20,2)
      DOUBLE PRECISION A(4,4),PIVOT(20)
      EQUIVALENCE (IROW,JROW),(ICOLUM,JCOLUM),(AMAX,T,SWAP)
      IF(N.NE.1) GO TO 20
      DET=A(1,1)
      A(1,1)=1./A(1,1)
      GO TO 18
   20 DET=1.
      DO 1 J=1,N
    1 IPIVOT(J)=0
      DO 14 I=1,N
      AMAX=0.
      DO 6 J=1,N
      IF(IPIVOT(J).EQ.1) GO TO 6
    2 DO 5 K=1,N
      IF(IPIVOT(K)-1)3,5,18
    3 IF(DABS(AMAX)-DABS(A(J,K)))4,5,5
    4 IROW=J
      ICOLUM=K
      AMAX=A(J,K)
    5 CONTINUE
    6 CONTINUE
      IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
      IF(IROW-ICOLUM)7,9,7
    7 DET=-DET
      DO 8 L=1,N
      SWAP=A(IROW,L)
      A(IROW,L)=A(ICOLUM,L)
    8 A(ICOLUM,L)=SWAP
    9 INDEX(I,1)=IROW
      INDEX(I,2)=ICOLUM
      PIVOT(I)=A(ICOLUM,ICOLUM)
      DET=DET*PIVOT(I)
      A(ICOLUM,ICOLUM)=1.
      DO 10 L=1,N
   10 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT(I)
   11 DO 14 L1=1,N
      IF(L1.EQ.ICOLUM) GO TO 14
   12 T=A(L1,ICOLUM)
      A(L1,ICOLUM)=0.
      DO 13 L=1,N
   13 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
   14 CONTINUE
      DO 16 I=1,N
      L=N+1-I
      IF(INDEX(L,1).EQ.INDEX(L,2)) GO TO 16
      JROW=INDEX(L,1)
      JCOLUM=INDEX(L,2)
      DO 16 K=1,N
      SWAP=A(K,JROW)
      A(K,JROW)=A(K,JCOLUM)
      A(K,JCOLUM)=SWAP
   16 CONTINUE
   18 RETURN
      END
```

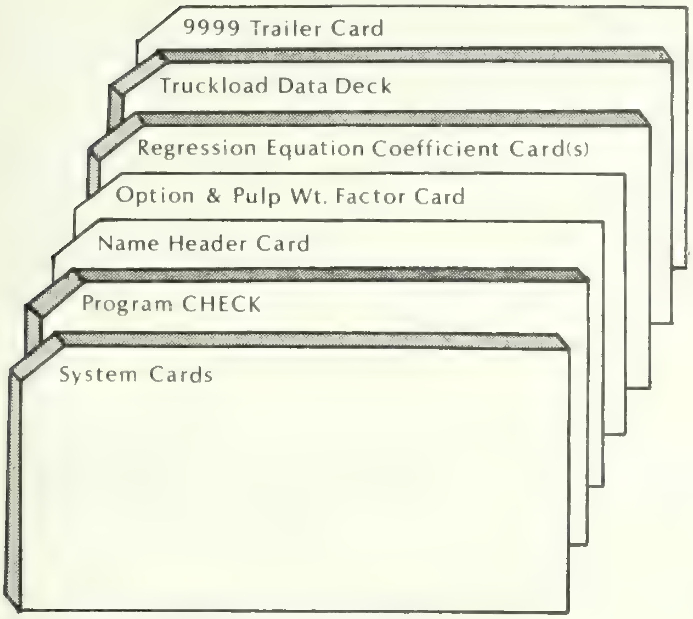
Appendix 2e. Listing for MULT

```
      SUBROUTINE MULT(A,B,N,L,M,C)
      DIMENSION A(N,M),B(M,L),C(N,L)
      DOUBLE PRECISION A,B,C
      DO 10 I=1,N
      DO 10 J=1,L
      C(I,J)=0.
      DO 10 K=1,M
   10 C(I,J)=C(I,J)+A(I,K)*B(K,J)
      RETURN
      END
```

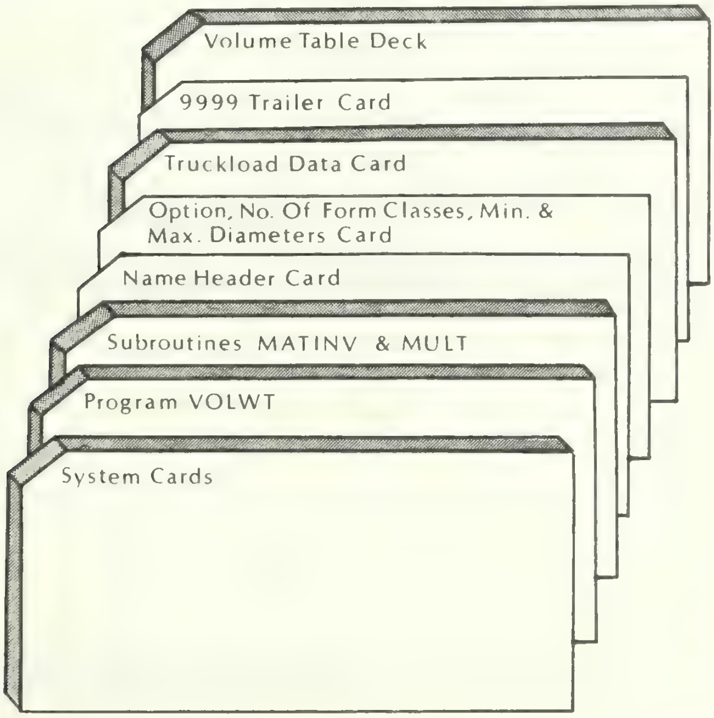
Appendix 3a. Illustration of deck setup for WTVOL


9999 Trailer Card
Truckload Data Deck
Option, Pulp Wt. Factor, Min. & Max.-No. Of Trees, Min. & Max.-Load Wt. Card
Name Header Card
Subroutines MATINV & MULT
Program WTVOL
System Cards

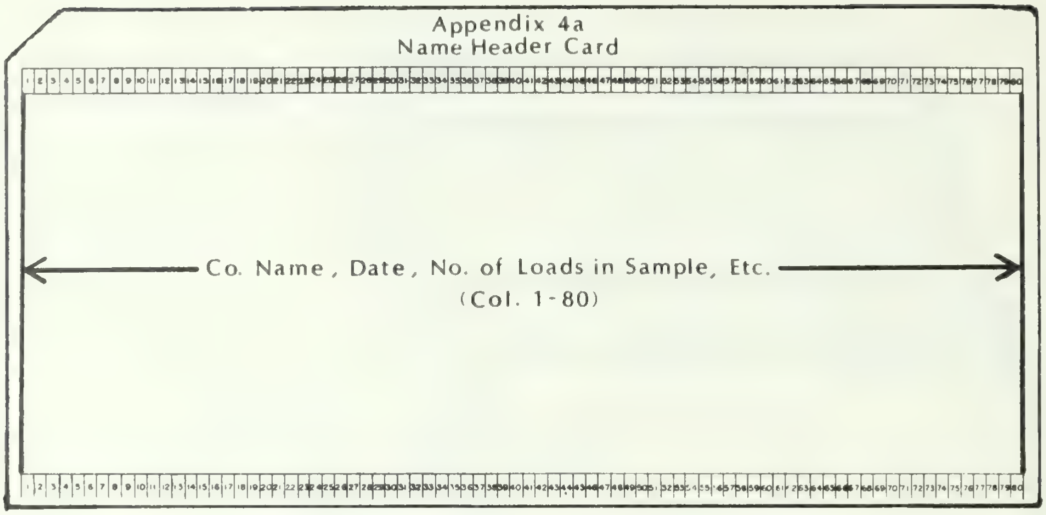
Appendix 3b. Illustration of deck setup for CHECK

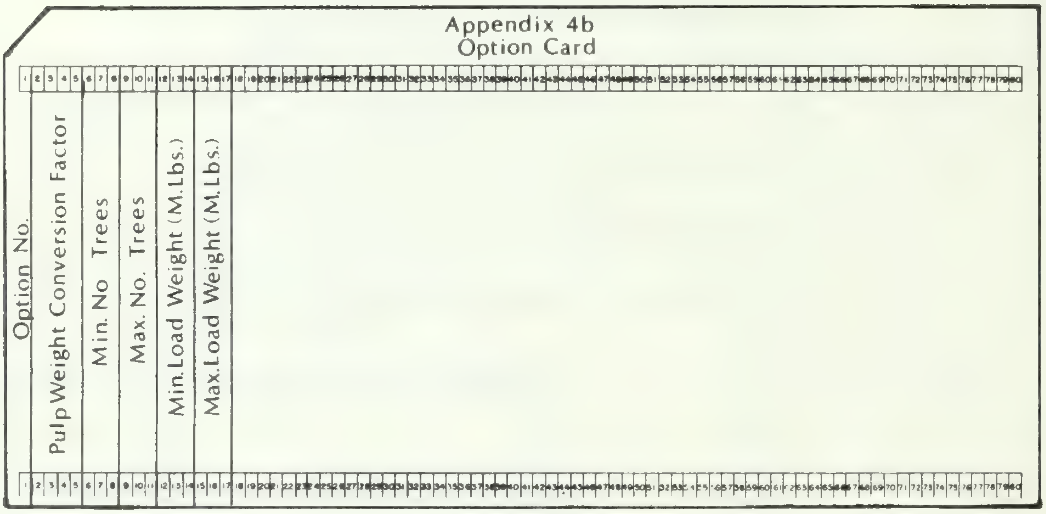


Appendix 3c. Illustration of deck setup for VOLWT

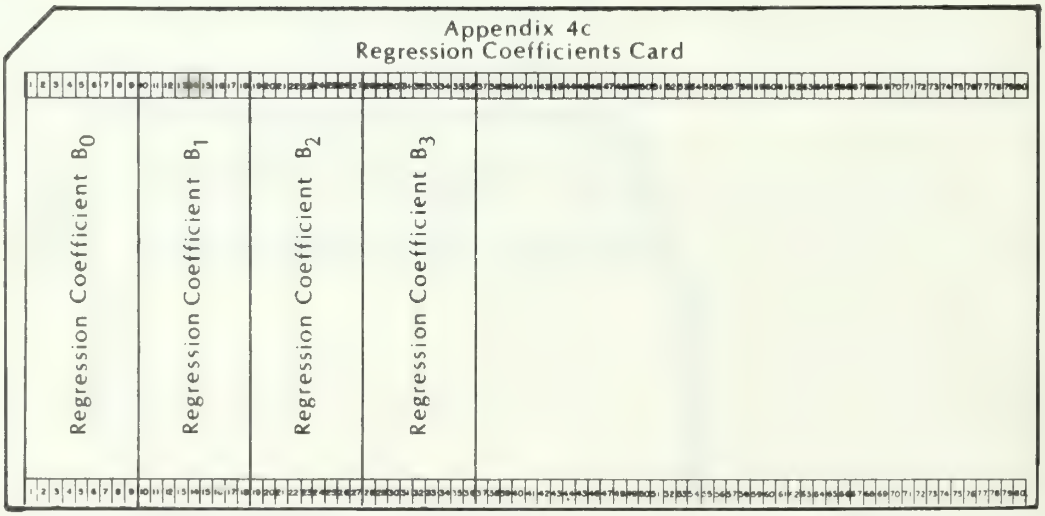


Appendix 4. Data formats


Appendix 4a
Name Header Card

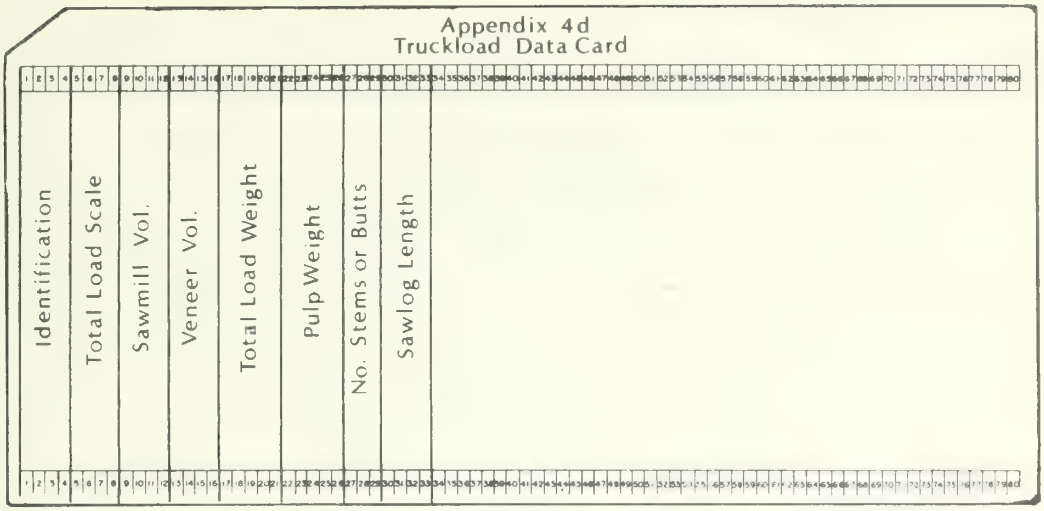

Appendix 4b
Option Card

Option No.
Pulp Weight Conversion Factor
Min. No Trees
Max. No. Trees
Min. Load Weight (M.Lbs.)
Max. Load Weight (M.Lbs.)

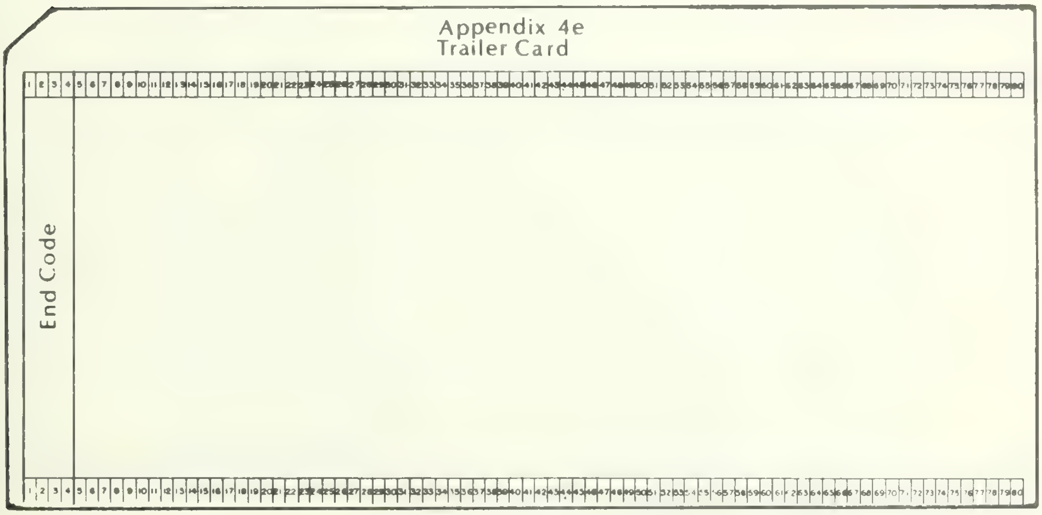

Appendix 4c
Regression Coefficients Card

Regression Coefficient B_0
Regression Coefficient B_1
Regression Coefficient B_2
Regression Coefficient B_3

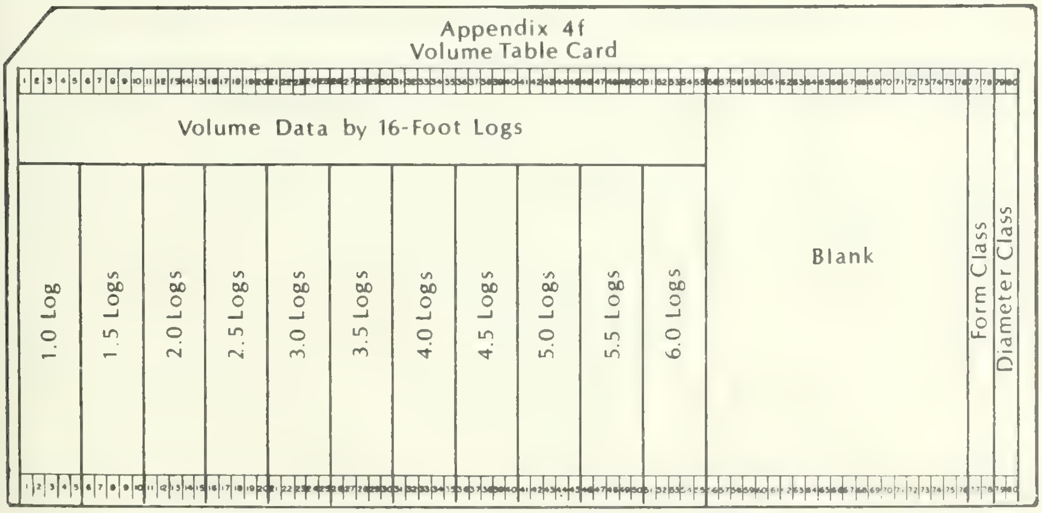
Appendix 4d
Truckload Data Card



Appendix 4e
Trailer Card



Appendix 4f
Volume Table Card



☆U.S. G.P.O.: 1974-747-899/1420, Region No. 4

Tyre, Gary L., Fasick, Clyde A., Riley, Frank M., Jr.,
and Lege, Frank O.
1973. Program manual for producing weight-scaling conversion tables. Southeast. For. Exp. Stn., USDA For. Serv. Gen. Tech. Rep. SE-3, 43 pp.

Three computer programs are presented which can be applied by individual firms to establish a weight-scaling information system. The first generates volume estimates from truckload weights for any combination of veneer, sawmill, and pulpwood volumes. The second provides quality-control information by tabulating differences between estimated volumes and observed check-scale volumes. The third produces weight estimates from volumes and generates tables that can be used to relate back to stumpage sales and current harvesting operations. The system depends upon regression analysis.

The Forest Service, U. S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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DA Forest Service General Technical Report SE-4 August 1974

Flood Frequencies and Bridge and Culvert Sizes for Forested Mountains of North Carolina

by

James E. Douglass

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Forest Service - U.S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

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Franklin, North Carolina

INTRODUCTION

Executive Order 11296, issued in August 1966, expresses the Federal Government's concern over mounting losses of lives and property as a result of floods in the United States. This order requires all Federal executive agencies to evaluate flood hazards when planning or constructing Federal facilities, when carrying out programs involving land use planning, and when administering programs supported by Federal funds. At the request of the Office of Management and Budget, guidelines for Federal agencies were developed and published by the U.S. Water Resources Council (1972). Although headwater areas are recognized, these guidelines are oriented primarily toward problems in the flood plains, where risk to life and damage to property may occur from overflow of streams. However, guidelines are also needed for headwater areas, where private individuals and State and Federal agencies must estimate flood flows in order to design culverts, bridges, and other structures.

Because of their simplicity, empirical formulas have been widely used to estimate discharge. Chow (1962) reviewed over 100 empirical or semiempirical formulas for estimation of flood flow. He found that in 1852 John Roe had prepared a drainage table of sewer sizes and slopes for the city of London. In this country, Major E. T. C. Meyers was one of the first engineers to propose a formula for determining waterway area. Chow also surveyed all State Highway Departments and found that 58 percent of those who responded used A. N. Talbot's 1887 formula, with or without modification, for determining waterway area. Use of empirical formulas has limitations and disadvantages. Many such formulas were derived for specific areas and conditions and cannot be applied to other areas or conditions. Formulas such as Talbot's often contain a coefficient to adjust the basic equation for local conditions, but selection of the proper coefficient requires testing and good judgment. Furthermore, the probability of the recurrence of floods of given sizes is often disregarded in empirical formulas.

Because knowledge of expected flow discharges from small forested watersheds is needed for realistic design of culverts and bridges, a study was made of the recurrence interval of flood flows from forested lands in the Blue Ridge Province of North Carolina. Relationships between discharge at recurrence intervals and drainage area and elevation are presented in this paper. Capacity tables for several types and sizes of culverts are also presented to simplify problems in culvert design for both the engineer and nonengineer.

DESCRIPTION OF AREA

Data used in this analysis came from two sources: experimental forested watersheds, approximately 0.1 to 3 sq. mi. in size, operated by the Forest Service at the Coweeta Hydrologic Laboratory near Franklin, North Carolina; and predominantly forested watersheds, approximately 13 to 50 sq. mi. in size, located west of Asheville, North Carolina, and gaged by U.S. Geological Survey. All of these watersheds lie within the Blue Ridge Province of the Appalachian Mountain Physiographic Division. Precipitation of the region is distributed fairly evenly throughout the year, and snow constitutes only about 5 percent of the total. Annual rainfall totals about 50 inches in the Asheville vicinity and increases generally with elevation and in a southwesterly direction from Asheville. The depth-duration of rainstorms also follows a similar pattern. The Coweeta Hydrologic Laboratory lies within one of the regions with the highest rainfall in the East, with rainfall at the Laboratory varying from an average of 70 inches at 2,200 ft. to approximately 100 inches at 5,000 ft. Rainfall from convection storms predominates during the summer months, whereas precipitation during the dormant season is usually associated with frontal activity. Hurricanes occasionally influence rainfall in the mountains, and flood flows may originate from convection, frontal, or hurricane sources.

Elevations of all gaging stations in the study are 2,200 ft. or greater. Maximum elevations of individual watersheds range from about 3,000 ft. for small watersheds within the Coweeta basin to over 6,000 ft. for some of the larger watersheds gaged by U.S. Geological Survey. Carolina gneiss of Pre-Cambrian origin forms a basement rock of granite gneiss, mica gneiss, and mica schist. The basement complex includes, in places, a thick series of late Pre-Cambrian sedimentary rock which has undergone metamorphosis. The weathered solum on slopes at lower elevations is often 50 or more feet deep, whereas soils are immature and shallow at elevations greater than 4,500 ft. Rock outcrops are fairly common above 5,000 ft. Soils which have developed under hardwood forests usually have infiltration rates greatly exceeding the maximum rate of rainfall observed in the area; therefore, overland flow is uncommon and most water reaches streams by subsurface flow. The drainage pattern is dendritic in shape, and stream density is high--often 10 mi. of streams occur per square mile of land area. Steeply sloping mountains, humid climate, and deep soils all combine to give relatively stable, year-round flows.

METHODS

Watersheds selected at Coweeta were covered with hardwoods and were either undisturbed or previously treated. If the watershed had some vegetative treatment in the past, the period when runoff would have been affected was deleted from the record and peak flows were estimated by the methods suggested by Dalrymple (1960).

Five Geological Survey watersheds in the same physiographic region were also suitable and selected for use. These watersheds were between 13 and 52 sq. mi. in size, had no significant urban or agricultural development, i.e., they were primarily forested, and contained no major impoundments or diversions of water which would materially affect peak discharge. Some physical and other characteristics of the watersheds are listed in table 1.

The flow-frequency methods described by Dalrymple (1960) were used to determine the recurrence interval of flood flows, to test the watershed data for homogeneity, and to formulate the relationship between discharge and drainage area.

The recurrence interval of each maximum discharge from the various watersheds was calculated by the formula

$$T = \frac{n + 1}{m} \qquad (1)$$

where T is the recurrence interval in years, i.e., the average interval of time within which the magnitude of the event will be equaled or exceeded once, n is the number of years of record, and m is the magnitude of flood, the highest being 1. Discharge was plotted over recurrence interval for each storm. Instead of a mathematically fitted line, a straight line was fitted to the data by eye. The graphical mean has been found to be more stable and dependable than the arithmetic mean because, with graphical means, greater weight is given to medium-sized floods than to extreme floods. Furthermore, the graphical mean is not adversely influenced by the chance inclusion or omission of a major flood. Care was taken to assure a good fit near the 2.33-year recurrence period, which is defined as the mean annual flood.

RESULTS

Figure 1 illustrates the relationship between peak discharge and recurrence interval for Coweeta Watershed 8 (2.9 sq. mi.) and for the Davidson River drainage (40 sq. mi.). In general, the relationship for smaller watersheds was a straight line when plotted on log-log paper; however, at recurrence intervals below 1.5 years, the data departed from the linear form and discharge decreased sharply as the recurrence interval dropped from 1.5 to 1.0 year. In contrast, the data for large watersheds plotted as curves on log-log paper, but they also showed decline in discharge at the lower recurrence intervals.

Table 1.--Physical and other characteristics of the watersheds used in the study of flow frequency in the Blue Ridge Province of North Carolina

Watershed[1]	Size	Elevation		Ratio[2] $\frac{Q_{10}}{Q_{2.33}}$	Adjusted years of record
		Maximum	Minimum		
	Sq. mi.	- - - - Ft. - - - -			No.
Coweeta					
1	0.0625	3,241	2,313	1.92	27
2	.0468	3,314	2,327	1.79	36
8	2.932	5,252	2,302	1.67	36
10	.3312	3,885	2,436	1.62	27
14	.2359	3,125	2,318	1.65	34
18	.0484	3,320	2,382	1.89	34
19	.1093	3,650	2,440	1.76	27
21	.0937	3,853	2,700	1.49	31
22	.1328	4,081	2,780	1.74	23
27	.1500	4,785	3,380	1.66	30
28	.5560	5,087	3,162	1.70	26
32	.1593	4,100	3,020	1.65	29
34	.1265	3,960	2,783	1.64	30
36	.1875	5,052	3,350	1.82	28
37	.1687	5,252	3,390	1.64	24
Davidson River	40.4	5,960	2,115	1.95	51
West Fork of Pigeon River	27.6	6,410	2,976	1.95	18
East Fork of Pigeon River	51.5	6,214	2,674	2.04	18
Nantahala River	51.9	5,499	3,073	1.72	31
Noland Creek	13.8	6,642	2,280	1.58	36

[1] Coweeta watersheds were completely forested; those gaged by U.S. Geological Survey were at least 90 percent forested.

[2] $\frac{\text{Discharge (Q) at recurrence interval of 10 years}}{\text{Discharge (Q) at recurrence interval of 2.33 years}}$.

A homogeneity test was conducted to ensure that data from the small experimental watersheds and the much larger and partially forested watersheds could be combined. This test is discussed by Dalrymple (1960) and is based on the Gumbel distribution. In the test, the discharges (Q) at recurrence intervals of 10 years and 2.33 years were used. The average ratio of $Q_{10}/Q_{2.33}$ was calculated and then multiplied by the discharge of the mean annual flood of each watershed.

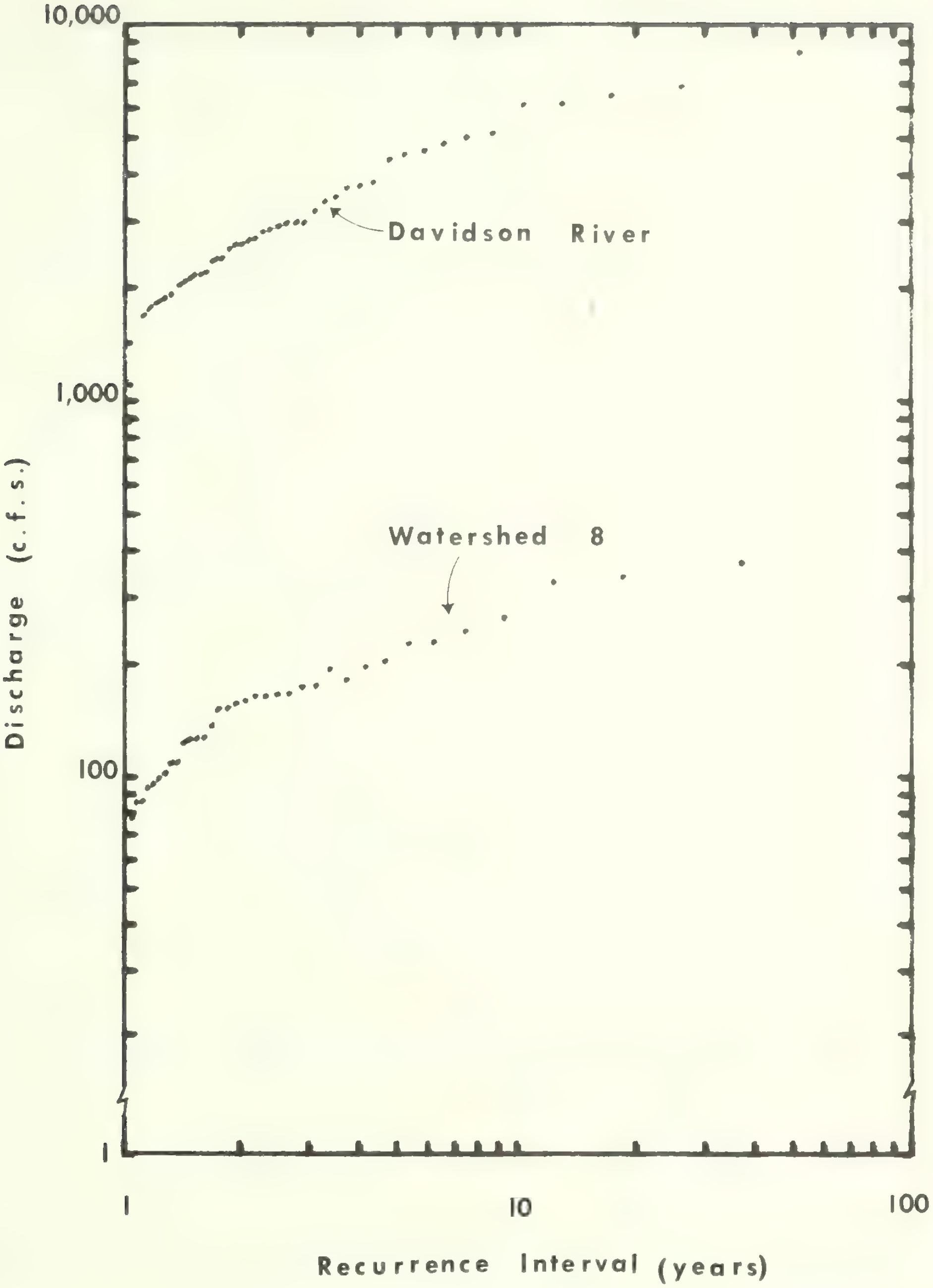

Figure 1.--Discharge vs. recurrence interval for Coweeta Watershed 8 (2.9 sq. mi.) and the Davidson River drainage (40 sq. mi.).

The recurrence interval for these discharges was then determined. The recurrence intervals are shown in figure 2, along with the upper and lower confidence limits computed for the 95-percent confidence interval.

Because the data for both large and small watersheds plotted within the confidence interval, the data could be combined into a regional frequency curve. However, the relationship of the mean annual flood on drainage area in square miles (fig. 3) showed considerable scatter, and

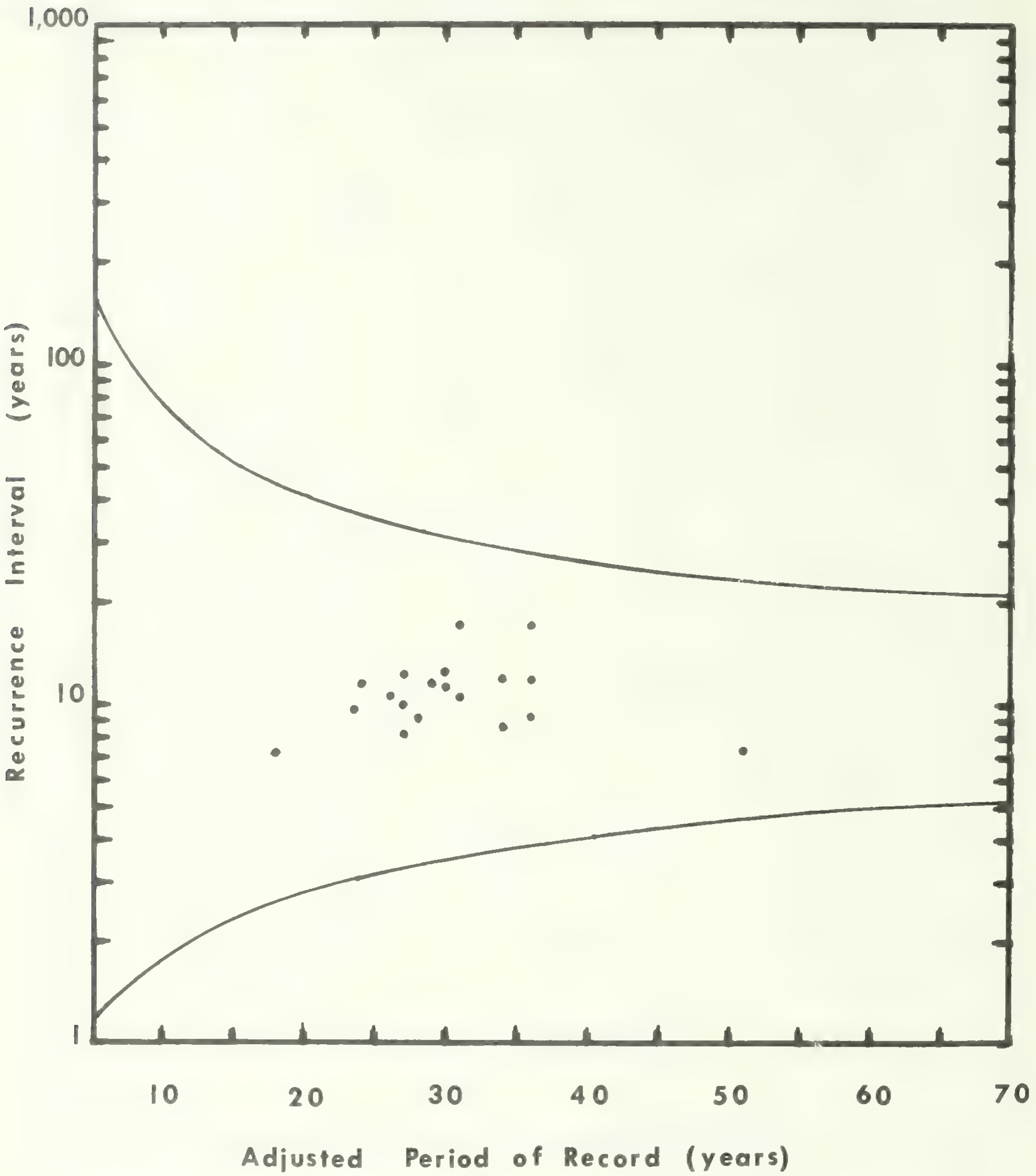

Figure 2.--Homogeneity of data for discharges at recurrence intervals of 10 years from both large and small watersheds. (The upper and lower lines are the 95-percent confidence limits.)

this scatter suggested that there is a major source of variation other than drainage area. Differences in slope, a decrease in soil depth with elevation, and an increase in precipitation with elevation for the area studied all suggested that some measure of the elevation of the watershed, either at the control, at midelevation, or at the maximum elevation along the ridge line, might integrate these effects and reduce the variation in flow between watersheds. Area and elevation are useful parameters in estimating discharge because both are easily determined from the 1:24,000-scale topographic maps of western North Carolina issued by the U.S. Army Corps of Engineers. The model which relates these variables to discharge is

$$Q_i = aA^bE^c \tag{2}$$

where Q_i is discharge in cubic feet per second for recurrence interval i, A is drainage area in acres, E is elevation of the watershed in feet, and a, b, and c are coefficients.

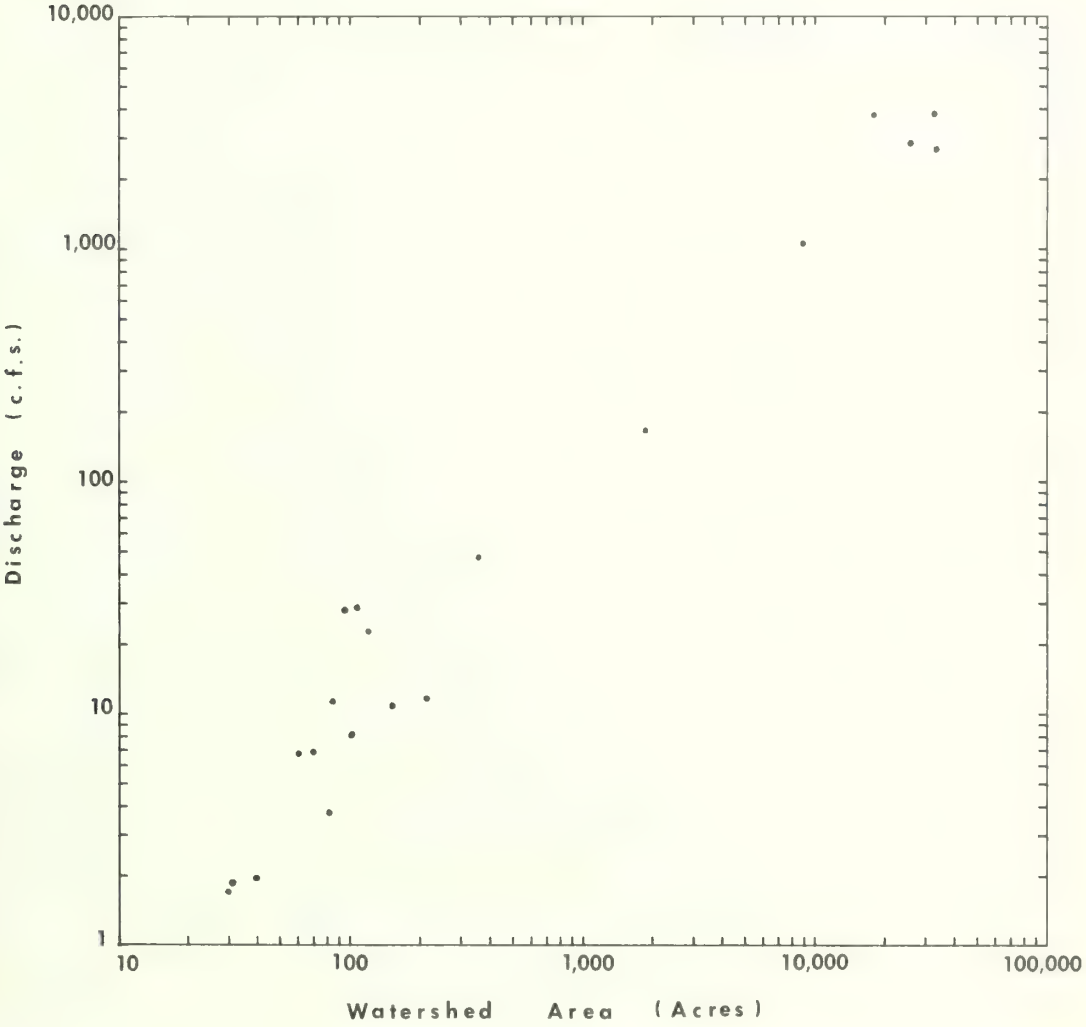

Figure 3.--Relationship between the mean annual discharge (2.33-year recurrence interval) and watershed area for both large and small watersheds.

The multiple regression in which both area and elevation were used was a significant improvement over the regression in which only drainage area was used as the independent variable. Elevation of the control and midelevation of the watershed both worked well, but they are more difficult to determine than the maximum elevation of the watershed. Therefore, elevation of the highest point on the watershed boundary was selected as the second independent variable. The r^2's for the equations were all greater than 0.98. Thus, 98 percent of the variation in discharge is explained by these equations when drainage area and maximum elevation are used. Any additional variables will not increase reliability significantly and will only serve to make these equations more difficult to apply. The derived equations for the 20 watersheds studied and their r^2's are listed below:

	Equation	r^2	
$\text{Log } Q_{2.33}$	$= -11.580 + 0.803 (\log A) + 3.038 (\log E)$	0.985	(3)
$\text{Log } Q_5$	$= -11.298 + 0.819 (\log A) + 2.986 (\log E)$	0.984	(4)
$\text{Log } Q_{10}$	$= -10.962 + 0.823 (\log A) + 2.920 (\log E)$	0.984	(5)
$\text{Log } Q_{20}$	$= -10.727 + 0.820 (\log A) + 2.887 (\log E)$	0.983	(6)
$\text{Log } Q_{30}$	$= -10.509 + 0.816 (\log A) + 2.846 (\log E)$	0.982	(7)
$\text{Log } Q_{40}$	$= -10.461 + 0.810 (\log A) + 2.848 (\log E)$	0.981	(8)
$\text{Log } Q_{50}$	$= -10.575 + 0.804 (\log A) + 2.893 (\log E)$	0.983	(9)

Figures 4 and 5 show the relationship between drainage area and elevation of the highest point on the watershed boundary for floods at recurrence intervals at 20 and 50 years. Comparison of discharges for the same elevation and drainage area indicates that discharge for the 50-year flood is approximately 1.4 times greater than the discharge for the 20-year flood. In comparison, an increase of 500 ft. in watershed elevation for floods of the same recurrence interval increases discharge by a factor of about 1.3 to 1.6. This relationship demonstrates that elevation of the catchment is critical in estimating peak discharge in the North Carolina mountains.

Also plotted in figure 5 is the discharge predicted by Talbot's formula for calculating waterway area in the mountains if a velocity of flood flow of 6 ft./sec. is assumed. Designing waterway areas by Talbot's formula would result in substantial overdesign for the 50-year flood, even for a watershed with a maximum elevation of 6,500 ft. The overdesign would be progressively greater as maximum elevation of the watershed decreased or as velocity of flood flow increased.

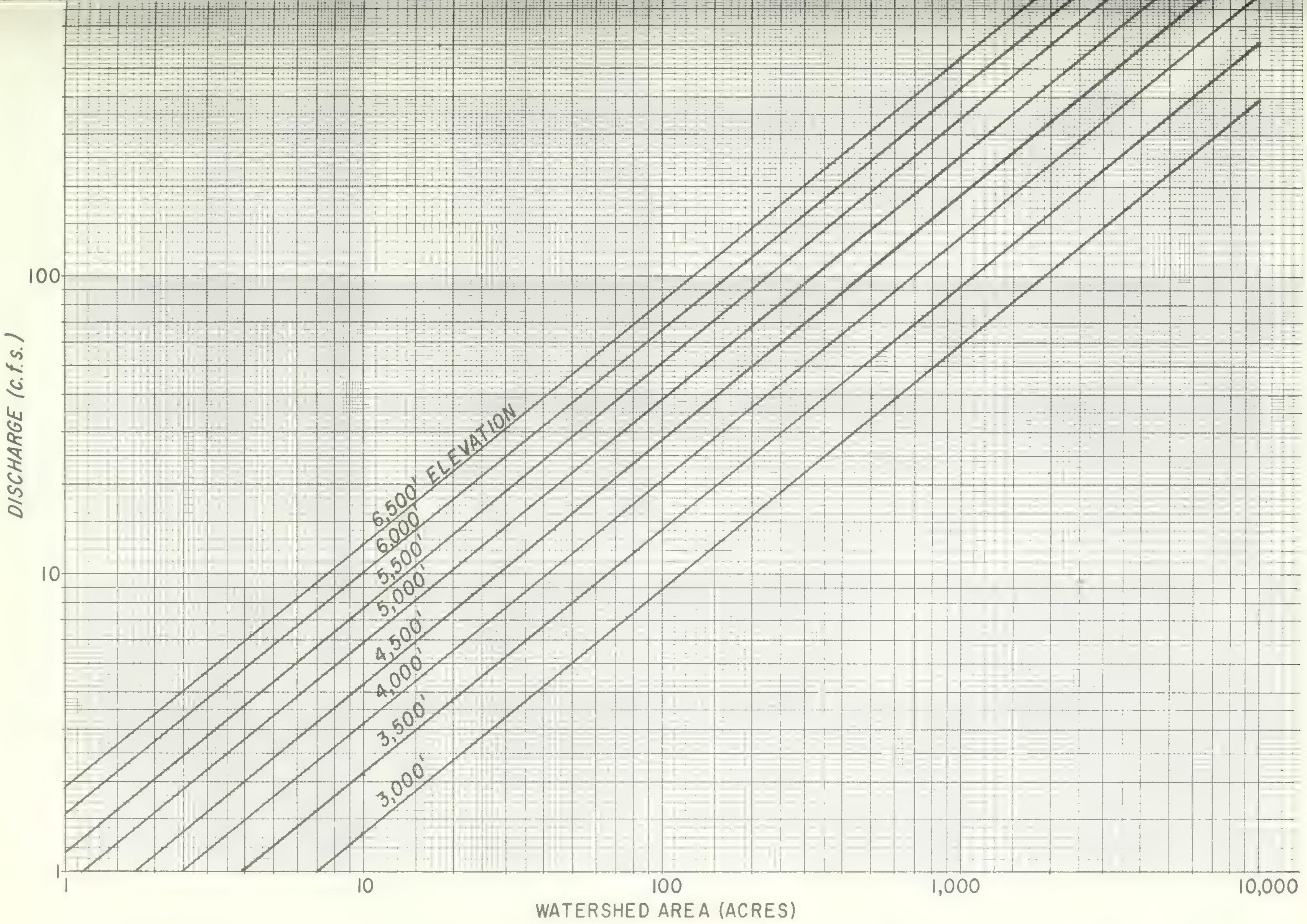

Figure 4.--Discharge for floods at recurrence intervals of 20 years according to drainage area and elevation of the watershed at its highest point.

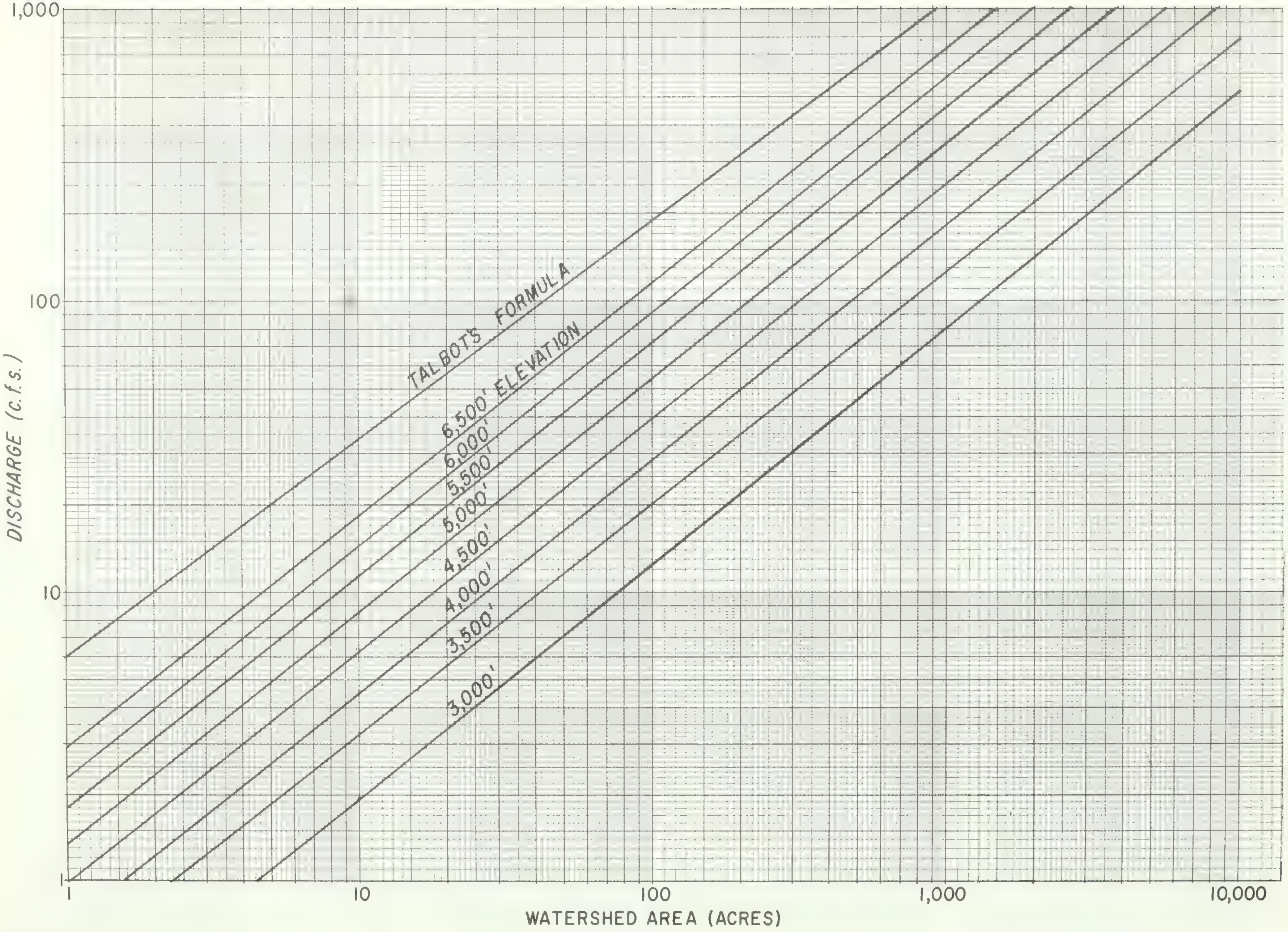

Figure 5.--Discharge for floods at recurrence intervals of 50 years according to drainage area and elevation of the watershed at its highest point. Talbot's formula for waterway area through which the flow must pass is C $\sqrt[4]{\text{acres}^3}$

Geological Survey conducted an analysis of flood frequency for North Carolina in which areas were designated according to their response to rainfall and their peak discharges (Forrest and Speer 1961). Of the watersheds gaged by Geological Survey, those used in my study fall within hydrologic areas 1 and 2 as designated by Forrest and Speer. When equation (3) was solved for area and maximum elevation, four of these five watersheds fell closest to their assigned hydrologic area. The slope of equation (3), however, is somewhat greater than that presented for hydrologic areas 1 and 2. This disparity suggests that perhaps the slope of the relationship between discharge and drainage area changes as watershed area decreases to small-sized drainages. Thus, considerable error may be introduced if the Geological Survey curves for hydrologic areas are extrapolated to smaller-sized drainage than indicated or if equation (3) is extrapolated to watersheds larger than 50 sq. mi. Because the data used to derive equations (3) through (9) were for watersheds with maximum elevations of 3,000 ft. or greater, the equations are not applicable for elevations below 3,000 ft. The equations also should not be applied to areas outside the Blue Ridge Province of North Carolina or to areas larger than 50 sq. mi. until the applicability of the equations to those areas has been determined.

APPLICATION TO CULVERT AND BRIDGE DESIGN

Once the discharge of a drainage can be estimated with reliability, the next problem in design is to determine the waterway area to carry this flow. In bridge design, the structure must be able to pass the discharge for which it was designed without damage to the structure or the channel downstream. Three factors are of primary concern: designed discharge (Q), which can be obtained from the equations or graphs presented; waterway area through which the flow must pass (A); and velocity of flow (V). The basic equation by Chezy for determining flow of water in open channels is written as follows:

$$Q = AV \tag{10}$$

or, solving for waterway area:

$$A = Q/V \tag{11}$$

A measure of velocity can be obtained by solving Manning's formula (American Iron and Steel Institute 1967; Spindler 1958), which considers slope, wetted perimeter, and roughness of the channel. A second and preferable approach is to use the actual stream velocity determined for major floods in the area in question. For mountain streams, measured channel velocity varies from about 10 to 25 ft./sec. for major floods on large watersheds (Tennessee Valley Authority 1961, 1963, 1964); in the smaller watersheds such as those at Coweeta, velocity for the 20- to 50-year flood is much lower, ranging from about 5 to 7 ft./sec. If the lower velocity for floods at recurrence intervals of 20 years or greater is used, equation (11) can be solved to obtain a conservative estimate of the waterway area required to pass flood peaks. For example, discharge for the 50-year flood from a 640-acre watershed with a maximum elevation of 3,000 ft. is about 55 c.f.s. (from equation (9) or figure 5). If an average velocity of 5 ft./sec. is assumed, a waterway area of 11 sq. ft. would be required to carry this flow.

Selection of the proper culvert size for designed discharge is much more difficult. There is no unique solution for a particular size or type of culvert. The required culvert size depends upon whether flow through the culvert is controlled at the inlet or outlet. Inlet control means that the culvert discharge is controlled at the entrance by depth of headwater (HW), entrance geometry including culvert shape and cross-sectional area, and the type of inlet edge (fig. 6). In outlet control, slope (S), Length (L), and roughness of the culvert are additional considerations.

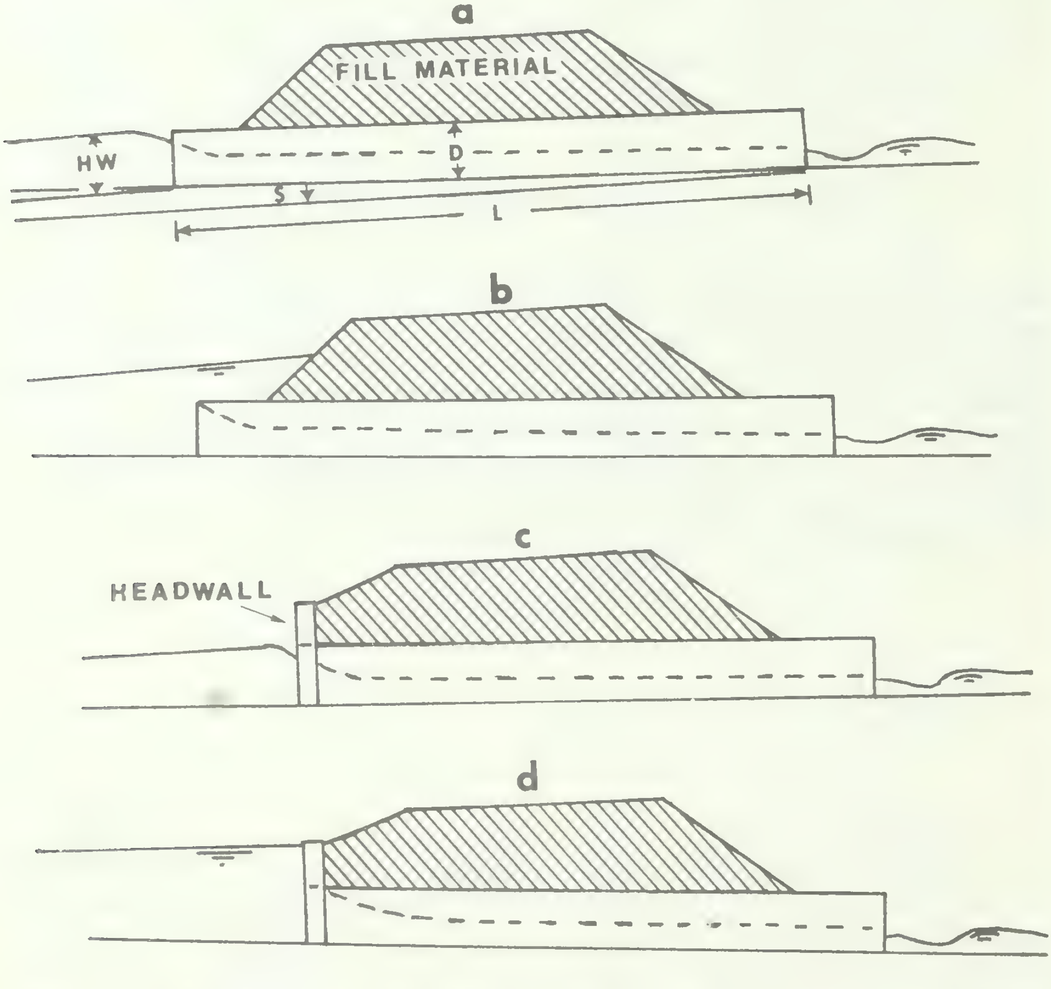

Figure 6.--Inlet control for two types of culverts and two depths of headwater. Schematics a and b illustrate culverts which project into the inlet basin. In a, headwater depth (HW) is equal to the culvert diameter (D) or rise of pipe-arch culverts; in b, headwater depth is greater than culvert diameter. The two examples of headwater depth are shown for culverts with headwalls in c and d. Other dimensions are culvert length (L) and slope (S).

The Federal Highway Administration recently developed relationships between headwater and discharge for various types of circular and pipe-arch culverts. These relationships, which are based on laboratory models, prototype testing, and experimental data, are presented as a series of nomographs. For a more complete discussion of inlet and outlet control and for the nomographs, Hydraulic Engineering Circulars 5 and 10 should be consulted (Herr and Bossy 1965a, 1965b).

Fortunately, for most situations in mountainous streams, inlet control will prevail. Culvert lengths will often be short, slopes will be relatively steep, and length and barrel slope can be ignored. Because most natural channels are wide in comparison with culvert diameter, the depth of water in the natural channel is considerably less than the critical depth of water in the pipe; thus, critical depth will not be a limitation. Unless the channel is restricted below the culvert by terrain features, debris, or protruding rocks (which will reduce the velocity of water discharging from the culvert), inlet control can usually be assumed for mountain streams.

As the headwater depth at the entrance of the culvert increases, the discharge capacity of the culvert increases. For design purposes, the minimum headwater depth should be set equal to the height (or diameter) of the culvert. For landowners who do not know the exact depth of fill which will cover the culvert, culvert size should be selected so that the ratio of headwater depth to culvert diameter will equal unity. In this situation, the culvert will not flow completely full (pipe flow), but more important, the water level in the inlet basin will not exceed the culvert height predetermined for the designed discharge. If engineers design for HW/D ratios greater than 1, they can take advantage of the greater discharge capacity of culverts. For example, the culvert capacity when the HW/D ratio is 2.0 is approximately twice that of the same culvert diameter when the HW/D ratio is 1. Thus, a smaller (and less expensive) culvert can be selected if the engineer will permit water to pond occasionally against the fill above the top of the culvert.

To aid the landowner or engineer in selecting appropriate culvert diameters, capacity tables (tables 2, 3, 4, and 5) were developed for inlet control on the basis of Hydraulic Engineering Circulars 5 and 10. Because friction in long culverts and low culvert slopes reduce culvert capacity and may change control from inlet to outlet, these tables contain a guide to ratios of length to slope (L/100S) for each culvert diameter. As long as these L/100S ratios are not exceeded and downstream flow is not restricted by terrain, debris, or rocks, inlet control may be assumed for mountainous conditions. When these conditions are not met, the tables should not be used and Hydraulic Engineering Circulars 5 and 10 should be consulted.

Table 2.--Capacity of standard circular pipes of corrugated metal with projecting end and inlet control[1]

Pipe diameter (inches)	Ratio[2] L/100S	Capacity of pipe with HW/D ratio[3] of--										
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
							c.f.s.					
12	5	2.1	2.3	2.6	2.7	2.9	3.1	3.3	3.6	3.8	4.0	4.2
15	5	3.7	4.1	4.4	4.8	5.1	5.5	5.8	6.2	6.6	6.9	7.2
18	10	5.8	6.4	7.0	7.5	8.1	8.7	9.2	9.8	10.3	10.9	11.4
21	15	8.6	9.4	10.2	11.1	11.9	12.7	13.5	14.4	15.2	16.0	16.8
24	20	12.0	13.1	14.3	15.4	16.6	17.7	18.9	20.0	21.2	22.3	23.5
27	25	16.1	17.6	19.2	20.7	22.3	23.8	25.4	26.9	28.4	30.0	31.5
30	30	20.9	22.9	24.9	27.0	29.0	31.0	33.0	35.0	37.0	39.0	41.0
33	40	26.5	29.1	31.6	34.2	36.7	39.3	41.8	44.4	46.9	49.5	52.0
36	50	32.9	36.1	39.3	42.5	45.7	48.8	52.0	55.1	58.3	61.4	64.6
42	60	48.4	53.1	57.8	62.4	67.1	71.8	76.4	81.0	85.7	90.3	94.9
48	80	67.5	74.1	80.6	87.1	93.6	100.1	106.6	113.1	119.6	126.0	132.5
54	100	90.6	99.4	108.2	116.9	125.6	134.4	143.1	151.8	160.4	169.1	177.8
60	130	117.8	129.3	140.7	152.1	163.5	174.8	186.1	197.4	208.7	220.0	231.2
66	150	149.5	164.0	178.5	193.0	207.4	221.8	236.1	250.5	264.8	279.1	293.4
72	170	185.8	203.8	221.8	239.8	257.7	275.6	293.4	311.2	329.0	346.8	364.5
78	200	226.8	248.9	270.9	292.8	314.7	336.5	358.3	380.1	401.8	423.5	445.2
84	230	273.0	299.5	326.0	352.3	378.7	404.9	431.2	457.4	483.5	509.6	535.7
90	265	324.4	355.8	387.2	418.6	450.0	481.1	512.2	543.3	574.4	605.4	636.4
96	300	381.0	418.0	454.9	491.7	528.5	565.2	601.8	638.3	674.8	711.2	747.6

[1] Based on Hydraulic Engineering Circulars 5 and 10 (Herr and Bossy 1965a, 1965b).

[2] L = length of culvert; S = slope of culvert.

[3] HW = headwater depth; D = diameter of culvert.

Table 3.--Capacity of standard circular pipes of corrugated metal with headwalls and inlet control

Pipe diameter (inches)	Ratio[2] L/100S	Capacity of pipe with HW/D ratio[3] of--										
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
							c.f.s.					
12	5	2.4	2.6	2.8	3.1	3.3	3.6	3.8	4.0	4.3	4.5	4.8
15	5	4.1	4.5	4.9	5.4	5.8	6.2	6.6	7.1	7.5	7.9	8.3
18	10	6.5	7.1	7.8	8.5	9.1	9.8	10.5	11.1	11.8	12.5	13.1
21	15	9.5	10.5	11.5	12.4	13.4	14.4	15.4	16.4	17.3	18.3	19.3
24	20	13.3	14.6	16.0	17.4	18.7	20.1	21.5	22.8	24.2	25.6	26.9
27	25	17.8	19.6	21.5	23.3	25.1	27.0	28.8	30.6	32.5	34.3	36.1
30	30	23.2	25.6	27.9	30.3	32.7	35.1	37.4	39.8	42.2	44.6	47.0
33	40	29.4	32.4	35.4	38.4	41.5	44.5	47.5	50.5	53.6	56.6	59.6
36	50	36.5	40.3	44.0	47.8	51.5	55.3	59.0	62.8	66.6	70.3	74.1
42	60	53.7	59.2	64.7	70.2	75.7	81.2	86.7	92.2	97.8	103.3	108.9
48	80	74.9	82.6	90.2	97.9	105.6	113.3	121.0	128.7	136.5	144.2	151.9
54	100	100.5	110.8	121.1	131.4	141.7	152.0	162.4	172.7	183.1	193.5	203.9
60	130	130.8	144.1	157.5	170.9	184.3	197.7	211.2	224.7	238.2	251.7	265.2
66	150	165.9	182.8	199.8	216.8	233.8	250.8	267.9	285.0	302.1	319.2	336.4
72	170	206.1	227.1	248.2	269.3	290.5	311.7	332.9	354.1	375.4	396.6	418.0
78	200	251.7	277.4	303.1	328.9	354.7	380.6	406.5	432.4	458.4	484.3	510.4
84	230	302.8	333.7	364.7	395.7	426.8	452.9	489.0	520.2	551.5	582.7	614.0
90	265	359.7	396.4	433.2	470.0	506.9	543.9	580.9	618.0	655.1	692.2	729.4
96	300	422.5	465.7	508.9	552.2	595.5	639.0	682.4	726.0	769.6	813.2	856.9

[1] Based on Hydraulic Engineering Circulars 5 and 10 (Herr and Bossy 1965a, 1965b).

[2] L = length of culvert; S = slope of culvert.

[3] HW = headwater depth; D = diameter of culvert.

Table 4. --Capacity of standard pipe-arches of corrugated metal with projecting end or headwalls and inlet control[1]

Pipe dimensions (inches)	Ratio[3] L/100S	Capacity of pipe-arch with HW/D ratio[3] of--										
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
		c.f.s.										
WITH PROJECTING END												
18 x 11	10	3.0	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.3	5.5	5.8
22 x 13	15	4.7	5.2	5.6	6.1	6.5	6.9	7.4	7.8	8.2	8.7	9.1
25 x 16	20	6.9	7.6	8.2	8.9	9.5	10.2	10.8	11.4	12.1	12.7	13.3
29 x 18	25	9.6	10.5	11.4	12.3	13.2	14.1	15.0	15.9	16.8	17.6	18.5
36 x 22	35	16.7	18.3	19.9	21.4	23.0	24.5	26.0	27.6	29.1	30.6	32.1
43 x 27	50	26.2	28.7	31.1	33.6	36.0	38.4	40.8	43.2	45.6	48.0	50.4
50 x 31	70	38.4	42.0	45.6	49.1	52.7	56.2	59.7	63.2	66.7	70.2	73.7
58 x 36	90	53.4	58.4	63.4	68.3	73.2	78.2	83.1	87.9	92.8	97.6	102.5
65 x 40	120	71.4	78.1	84.7	91.4	98.0	104.5	111.1	117.6	124.1	130.6	137.0
72 x 44	150	92.6	101.2	109.9	118.5	127.0	135.6	144.1	152.5	160.9	169.3	177.7
WITH HEADWALLS												
18 x 11	10	3.3	3.7	4.0	4.3	4.7	5.0	5.3	5.6	6.0	6.3	6.6
22 x 13	15	5.3	5.8	6.3	6.8	7.3	7.8	8.4	8.9	9.4	9.9	10.4
25 x 16	20	7.7	8.5	9.2	10.0	10.8	11.5	12.3	13.0	13.8	14.5	15.3
29 x 18	25	10.7	11.8	12.8	13.9	14.9	16.0	17.1	18.1	19.2	20.2	21.3
36 x 22	35	18.6	20.5	22.3	24.2	26.0	27.8	29.7	31.5	33.3	35.2	37.0
43 x 27	50	29.3	32.2	33.1	38.0	40.9	43.8	46.6	49.5	52.4	55.3	58.2
50 x 31	70	42.9	47.2	51.4	55.7	59.9	64.1	68.4	72.6	76.8	81.0	85.2
58 x 36	90	59.8	65.7	71.6	77.5	83.4	89.3	95.2	101.1	106.9	112.8	118.7
65 x 40	120	80.1	88.0	95.9	103.8	111.7	119.6	127.5	135.4	143.2	151.1	159.0
72 x 44	150	104.0	114.3	124.5	134.8	145.1	155.3	165.5	175.8	186.0	196.2	206.4

Table 5.--Capacity of pipe-arches of structural-plate corrugated metal with 18-inch corner radii, projecting end or headwalls, and inlet control[1]

WITH PROJECTING END

Span size	Rise	Ratio[2] L/100S	Capacity of pipe-arch with HW/D ratio[3] of--										
			1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
			c.f.s.										
6 ft. 1 in. x	4 ft. 7 in.	40	128	140	152	164	176	188	200	212	224	235	247
7 ft. x	5 ft. 1 in.	50	174	191	207	224	240	257	273	289	305	322	338
8 ft. 2 in. x	5 ft. 9 in.	60	250	274	298	322	345	369	392	415	438	462	485
9 ft. 6 in. x	6 ft. 5 in.	70	341	373	405	438	470	502	533	565	597	628	660
11 ft. 5 in. x	7 ft. 3 in.	90	477	523	568	613	658	703	747	792	836	880	925
12 ft. 10 in. x	8 ft. 4 in.	120	683	747	812	877	941	1,005	1,068	1,132	1,195	1,259	1,322
15 ft. 4 in. x	9 ft. 3 in.	140	924	1,012	1,099	1,186	1,273	1,350	1,446	1,532	1,618	1,703	1,789
16 ft. 7 in. x	10 ft. 1 in.	170	1,168	1,279	1,390	1,500	1,610	1,719	1,828	1,937	2,046	2,154	2,262
WITH HEADWALLS													
6 ft. 1 in. x	4 ft. 7 in.	40	143	157	171	185	199	213	227	241	255	269	282
7 ft. x	5 ft. 1 in.	50	195	214	233	252	271	290	309	328	347	366	385
8 ft. 2 in. x	5 ft. 9 in.	60	279	307	334	361	389	416	443	470	498	525	552
9 ft. 6 in. x	6 ft. 5 in.	70	379	417	454	491	528	565	602	639	676	713	750
11 ft. 5 in. x	7 ft. 3 in.	90	531	583	635	687	739	791	843	894	946	998	1,049
12 ft. 10 in. x	8 ft. 4 in.	120	757	832	906	980	1,054	1,129	1,202	1,276	1,350	1,424	1,498
15 ft. 4 in. x	9 ft. 3 in.	140	1,023	1,124	1,224	1,325	1,425	1,525	1,625	1,725	1,825	1,924	2,024
16 ft. 7 in. x	10 ft. 1 in.	170	1,293	1,420	1,547	1,673	1,800	1,926	2,052	2,178	2,304	2,430	2,556

[1] Based on Hydraulic Engineering Circulars 5 and 10 (Herr and Bossy 1965a, 1965b).
[2] L = length of culvert; S = slope of culvert.
[3] HW = headwater depth; D = diameter of culvert.

Specific Examples

The following examples illustrate the use of the discharge relationships and capacity tables for culverts:

Example 1

Situation: A logging road is constructed to remove timber products intermittently at 10-year intervals for the foreseeable future. This road crosses several intermittent and perennial streams, but damage resulting from overflow of the culverts or bridges will be negligible except at the failure site. Therefore, the landowner decides to set the designed discharge equal to the expected life of the culvert, i.e., the discharge at the recurrence interval of 20 years. At a particular crossing site, the watershed above the site is 56 acres in size and the stream gradient is 10 percent. The maximum elevation of the 56-acre drainage area is 4,600 ft. If a culvert is used, a culvert length of 30 ft. will suffice at the site. The stream channel below the crossing contains no obstructions to flow.

Required: Discharge at the recurrence interval of 20 years, waterway area for a bridge to carry this discharge, and culvert type(s) and sizes which are suitable for use.

From equation (6) or figure 4, the discharge at the recurrence interval of 20 years is estimated to be 19 c.f.s. From equation (11) and an assumed flow velocity of 5 ft./sec., a bridge must provide

$$\frac{19 \text{ c.f.s.}}{5 \text{ ft./sec.}} = 3.8 \text{ sq. ft.}$$

of waterway area.

Because the HW/D ratio is not known in this example, a HW/D ratio of 1.0 should be used. From tables 2 and 3, a circular culvert of corrugated metal 30 inches in diameter with projecting end or headwalls would carry the designed discharge of 19 c.f.s. From table 4, a 43- by 27-inch pipe-arch with projecting end or headwalls would also carry the designed discharge. Applicability of the capacity tables for inlet control can be tested by calculating the L/100S ratio: 30/10 = 3, which is less than the L/100S ratios for these types and sizes of culverts. With this information, the designer of the road can select the most suitable and economical materials for bridging the stream.

Example 2

Situation: An engineer-designed, multipurpose forest road crosses a stream draining a 720-acre watershed. Maximum elevation is 5,450 ft.; stream gradient is 3 percent; elevation of the road surface on the centerline of the stream is to be 30.2 ft. above the stream channel at the culvert entrance; length of the culvert (if used) is 120 to 140 ft.; designed discharge is for a recurrence interval of 50 years. The channel below the crossing site contains no obstructions to flow.

Required: Discharge at the recurrence interval of 50 years, waterway area for a bridge, and culvert sizes and types.

From equation (9) or figure 5, the discharge at the recurrence interval of 50 years is 340 c.f.s. A waterway area of

$$\frac{340 \text{ c.f.s.}}{5 \text{ ft./sec.}} = 68 \text{ sq. ft.}$$

is required if the stream is to be spanned by a bridge. If the engineer chooses instead to use a culvert and does not want the depth of water to exceed the diameter of the culvert (i.e., a HW/D ratio of 1.0), a 96-inch culvert with projecting end or a 90-inch culvert with headwalls is required (tables 2 and 3). From table 5, a 9-ft. 6-inch by 6-ft. 5-inch pipe-arch of structural plate with projecting end or headwalls would carry the discharge. (The L/100S ratio is within the allowable limits for both the circular and the pipe-arch culverts.) If the engineer decides he will allow a headwater depth of twice the culvert diameter, a substantially smaller culvert can be used; a circular culvert of standard corrugated metal 72 inches in diameter with projecting end or headwalls would carry the designed discharge of 340 c.f.s. (tables 2 and 3). An 8-ft. 2-inch by 5-ft. 9-inch pipe-arch with projecting end or a 7-ft. by 5-ft. 1-inch pipe-arch with headwalls would also carry the designed discharge (table 5).

Example 3

Situation: Identical to example 2 except that the road surface will be 10 ft. above the channel surface of the culvert inlet, the HW/D ratio is 1.0, and fill depth over the culvert must be one-half the diameter of the culvert or one-half the span of the pipe-arch.

Required: Discharge at the recurrence interval of 50 years as previously determined, and culvert sizes.

In this situation, two or more culverts will be required and culvert diameter plus one-half culvert diameter must be less than 10 ft. If two circular culverts of corrugated metal are used, each must carry one-half of the designed discharge or 1.70 c.f.s. From tables 2 and 3, a circular culvert of corrugated metal 72 inches in diameter would carry 186 to 206 c.f.s. (depending on whether a projecting end or headwalls are used). The 6-ft. pipe diameter plus one-half pipe diameter equals 9 ft. Because this distance is less than the 10-ft. depth from stream channel to road surface, two 72-inch culverts could be used. Similarly, two 7-ft. by 5-ft. 1-inch pipe-arches could also be used (table 5).

SUMMARY

A method is presented for predicting flood discharge from the forested Blue Ridge Mountains of North Carolina for storms at recurrence intervals of 2.33, 5, 10, 20, 30, 40, and 50 years. These predictions are based on area and maximum elevation of the drainage. Once storm discharge has been estimated, the proper size of culvert can be determined from tables which list the discharge capacity of several types of culverts. Dimensions of the waterway area of bridges can also be estimated. Although these results were derived for the mountains of North Carolina, inclusion of discharge data from forested drainages of north Georgia, northwest South Carolina, and east Tennessee might be used to recalculate discharge relationships which would be applicable to a larger geographic area of the southern Appalachians.

ACKNOWLEDGMENT

Mr. Henry R. Stennett, Investigation Officer, Watershed Protection Commission, Kinston, Jamaica, assisted in this analysis, and his help with the study is greatly appreciated.

LITERATURE CITED

American Iron and Steel Institute
1967. Handbook of steel drainage and highway construction products. 368 p. New York: American Iron and Steel Institute.

Chow, V. T.
1962. Hydrologic determination of waterway area for the design of drainage structures in small drainage basins. Univ. Ill. Eng. Exp. Stn. Bull. 462, 104 p.

Dalrymple, T.
1960. Flood-frequency analyses--manual of hydrology: Part 3. Flood-flow techniques. USDI Geol. Surv. Water Supply Pap. 1543-A, 80 p.

Forrest, William E., and Speer, Paul R.
1961. Floods in North Carolina--magnitude and frequency. USDI Geol. Surv. in coop. with N.C. State Highw. Comm., Open-File Rep., Raleigh, N.C., 195 p.

Herr, Lester A., and Bossy, Herbert G.
1965a. Capacity charts for the hydraulic design of highway culverts. USDC Bur. Public Roads, Hydraul. Branch, Bridge Div., Off. Eng. & Oper., Hydraul. Eng. Circ. 10, 90 p.

________ and Bossy, Herbert G.
1965b. Hydraulic charts for the selection of highway culverts. USDC Bur. Public Roads, Hydraul. Branch, Bridge Div., Off. Eng. & Oper., Hydraul. Eng. Circ. 5, 54 p.

Spindler, W. H.
1958. Handbook of drainage and construction products. Armco Drain. & Metal Prod., Inc. 529 p. Chicago, Ill.: Lakeside Press, R. R. Donnelley & Sons Co.

Tennessee Valley Authority
1961. Flood on Piney River November 18-19, 1957 in the vicinity of Spring City, Tennessee. Div. Water Control Plann., TVA Rep. 0-6158, 93 p.

____
1963. Floods on Little Tennessee River, Cullasaja River and Cartoogechaye Creek in the vicinity of Franklin, North Carolina. Div. Water Control Plann., TVA Rep. 0-6193, 67 p.

____
1964. Floods on French Broad and Davidson Rivers and King, Nicholson, and Tucker Creeks in the vicinity of Brevard, North Carolina. Div. Water Control Plann., TVA Rep. 0-6373, 98 p.

U.S. Water Resources Council
1972. Flood hazard evaluation guidelines for Federal executive agencies. U.S. Water Resour. Counc., 22 p.

Douglass, James E.
1974. Flood frequencies and bridge and culvert sizes for forested mountains of North Carolina. Southeast. For. Exp. Stn., USDA For. Serv. Gen. Tech. Rep. SE-4, 21 p.

Accurate estimates of flood discharges from forested lands are needed for design of bridges and culverts. Equations incorporating watershed area and maximum elevation were developed for discharges at recurrence intervals of 2.33, 5, 10, 20, 30, 40, and 50 years from forested land in the Blue Ridge Province of North Carolina. These equations accounted for 98 percent of the variation in discharge. Capacity tables for several types and sizes of culverts are presented to simplify problems in culvert design.

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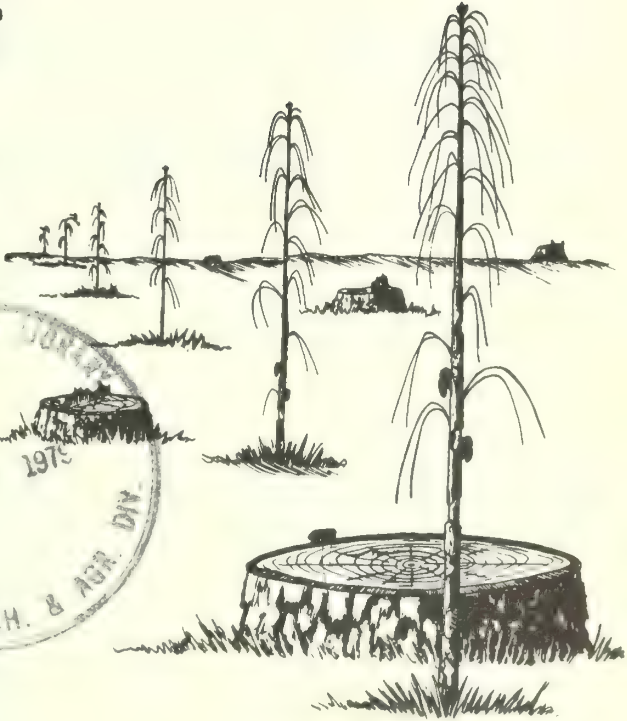
HOW TO PREVENT WEEVIL DAMAGE TO PINE SEEDLINGS IN THE SOUTH

y Charles F. Speers
nd Edward P. Merkel

U.S. Department of Agriculture
Forest Service
outheastern Forest Experiment Station
Asheville, North Carolina



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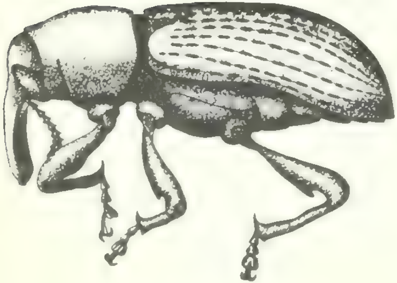
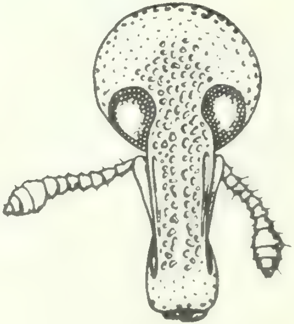
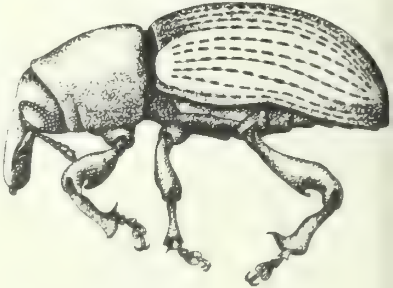
WHAT ARE PALES AND PITCHEATING WEEVILS?

Pales and pitcheating weevils are dark colored, robust, oblong, hard shelled snout beetles, $\frac{1}{4}$ to $\frac{1}{2}$ inch long. In the South these are the two principal species that damage pine seedlings.



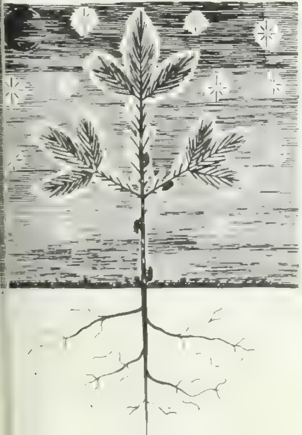
Pales weevil



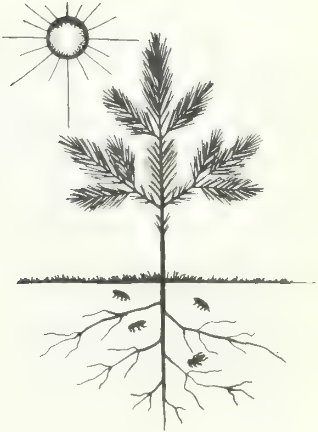


Pitcheating weevil

HOW ARE PINE SEEDLINGS KILLED?

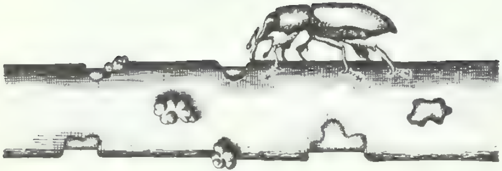


Weevils feed on trees at night



Weevils hide in the soil during the day

Weevils feed on the bark of seedlings above or below ground level, girdling the tree and causing its death. Weevils are seldom seen because they feed at night and hide in the soil during the day.

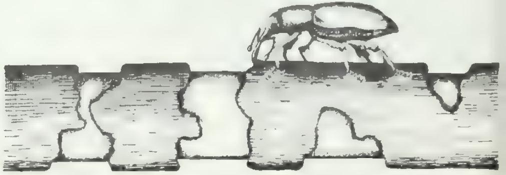


Light weevil feeding heals over

Light weevil feeding creates a series of pits in the bark which fill with resin and heal over. If feeding is heavy, the pits merge, the stem is girdled, and the tree is killed.

HOW CAN
WEEVIL DAMAG
BE
RECOGNIZED?

Heavy weevil feeding kills seedling



Logging

Fire

WHERE DO THE WEEVILS COME FROM?

Weevils are common throughout the South. They breed principally in the stumps and roots of recently cut pine trees, but they also breed in dying trees.

Lightning

Bug kills

WHY IS WEEVIL DAMAGE SO SERIOUS TO SEEDLINGS PLANTED ON CUTOVER LAND?

Weevils developing in logging material and dying trees throughout the forest are attracted to cutover areas by the odor of fresh resin. If the area is planted shortly after cutting, seedlings are heavily attacked by the adult beetles.

WHY IS DAMAGE HEAVY AFTER FALL SITE PREPARATION?

Adults are attracted into areas cutover in the spring and early summer. The brood of these weevils develops in the roots of stumps and emerges as new adults in the fall.

When unmerchantable trees are bulldozed during site preparation in the fall, these pines and the new slash attract weevils. These weevils, plus adults emerging from roots of the pines cut in the spring, are held in the area by the new material.

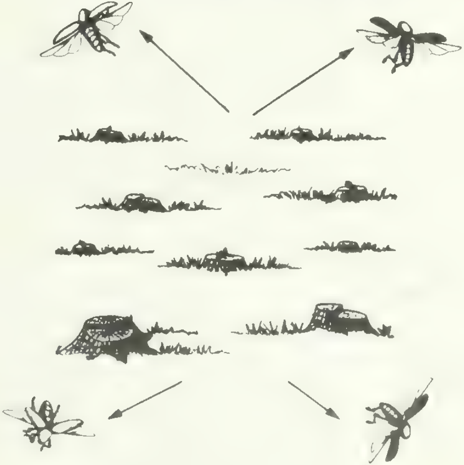
If pine seedlings are planted in the winter, extremely heavy weevil feeding will generally occur the following spring, summer, and fall.

WEEVIL DAMAGE CAN BE MINIMIZED BY TIMING OF CUTTING AND PLANTING

IF PINE IS CUT FROM NOVEMBER TO JUNE

Adults are attracted into cutover areas in the spring after winter cutting, and at the time of cutting in the spring and early summer.

Brood develops in the roots of stumps during he spring and summer.



Weevils emerge from stumps and roots in the fall and disperse to new cutting areas.

Plant during the winter and little or no weevil damage will occur. If seedlings are planted early in the fall, the weevils may feed on and kill seedlings before they disperse.

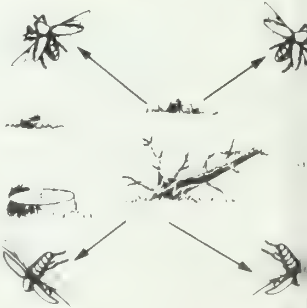
IF PINE IS CUT FROM JULY TO NOVEMBER

Adults are attracted into areas at the time of cutting

Brood develops in the roots of stumps during the fall and winter

Let the land lie fallow the first winter and the new weevils will emerge and disperse the following spring, summer, and fall

Plant your pine seedlings the following winter and they should be relatively safe from weevil damage



Caution: If seedlings are planted the first winter after harvest, heavy weevi damage to the trees will usually occur the following spring, summer, and fal

WHEN CUTTING AND PLANTING CANNOT BE TIMED FOR NATURAL CONTROL

Seedlings can be protected from weevil damage by dipping them in an insecticide prior to planting.

Chemicals used for insect control are constantly being replaced by more effective or safer compounds, and their use may be restricted in some states. Therefore, for the latest control recommendations in your State please contact your County Agent, State Forester, or Forest Service office.

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rrent Knowledge of Monodontomerus dentipes (Dalman), A Cocoon Parasite of Pine Sawflies

by

Vicki H. Fedde

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Forest Service - U.S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

Current Knowledge of Monodontomerus dentipes (Dalman),[1] A Cocoon Parasite of Pine Sawflies

by

Vicki H. Fedde, Associate Entomologist
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Research Triangle Park, North Carolina

Monodontomerus dentipes (Dalman), a European parasite of cocoons of pine sawflies, has been a key factor in the control of the introduced pine sawfly, Diprion similis (Hartig), in the United States and Canada. Several other Diprion and Neodiprion spp. have also been reported as hosts, and the sawflies which occur in the southeastern United States are possible targets for control by M. dentipes. During a recent study of the development and emergence of the parasite, a comprehensive survey of the literature on M. dentipes was made. The purpose of this review is to aid others in studying the insect so that its usefulness as an agent in the control of Neodiprion and Diprion spp. can be enhanced.

The original description of M. dentipes is generally credited to Dalman (1820) who described both sexes of the adult. A number of sources (Hartley 1923; Faure 1925; Sitowski 1929; de Fluiter 1933; Mokrezecki 1933; Scheidter 1934; Gahan 1941; Bucher 1948) incorrectly listed the description by Boheman (1833), based on a single female as having priority. Dalman named the parasite Torymis dentipedis and placed it in the family Pteromalidae, tribe Pteromalini. The species was transferred to Monodontomerus (Walker 1847), which at the time was in the family Callimomidae (Westwood 1833). The name Callimomidae has been permanently suppressed (Peck 1963). Monodontomerus has also been listed in the family Chalcididae (Howard and Ashmead 1898) but is presently in the family Torymidae (Gahan 1941). The species M. dentipes is synonymous with Torymus vicicellae Förster (Walker 1847) and M. viridaeneus Provancher (Burks 1963).

Several keys are available for the diagnosis of M. dentipes. Adults were separated from those of other Monodontomerus spp. by Gahan (1941) and Steffan (1952). A comprehensive list of references by species of Monodontomerus was provided by Burks (1963). Since there is little overlapping of the hosts of M. dentipes and other Monodontomerus spp., identification is simplified through the identification of the host, especially if the host is a diprionid sawfly (table 1). In North America, M. japonicus Ashmead and M. dentipes are the only Monodontomerus spp. which attack sawflies. The only record of M. japonicus on a North American sawfly is in Canada, where it was released against D. hercyniae (Hartig) (Finlayson and Finlayson 1958b). In the absence of further records of M. japonicus on D. hercyniae, it probably has not become established. M. dentipes was separated from other parasites of pine sawflies by Morris et al. (1937), Finlayson (1960a, 1960b, 1962, and 1963), Mertins (1967), and Mertins and Coppel (1971).

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[1] Hymenoptera: Torymidae.

Table 1.--Host families of *Monodontomerus dentipes* (Dalman) and some other *Monodontomerus* spp. with those parasites having host families in common with *M. dentipes* indicated by horizontal lines

Host	Parasite									
Order and family	*M. dentipes* (Dalman)	*M. aereus* Walker	*M. dianthidii* Gahan	*M. emarginatus* Gahan	*M. indiscretus* Gahan	*M. japonicus* Ashmead	*M. mandibularis* Gahan	*M. minor* (Ratzeburg)	*M. montevagus* Ashmead	*M. obscurus* Westwood
HYMENOPTERA										
Apidae									X	
Braconidae	X	X								
Chalcididae		X								
Cynipidae	X									
Diprionidae	X					X				
Ichneumonidae	X	X						X		
Megachilidae			X	X			X			X
Sphecidae									X	
Tenthredinidae					X					
Vespidae									X	
LEPIDOPTERA										
Arctiidae		X								
Lasiocampidae		X						X		
Liparidae	X									
Lymantriidae	X	X								
Olethreutidae	X							X		
Saturniidae								X		
Tortricidae	X	X						X	X	
Zygaenidae	X									
DIPTERA										
Tachinidae	X	X								

Description of Adults

The most complete treatment of the morphology of the adults of *M. dentipes* is a detailed study by Bucher (1948). He included numerous drawings with descriptions of the internal and external anatomy of both sexes.

Others have described the external anatomy of the adults (Morris et al. 1937, Gahan 1941, and Mertins and Coppel 1971), and Mertins (1967) includes an illustration of both sexes. The remarks that follow are mainly from Bucher (1948).

M. dentipes is larger than most chalcids. Its size depends largely on the size of the host and on the number of individuals that develop in one cocoon. Females are about 4.1 mm from the front of the head to the tip of the extended ovipositor, which measures 0.7 mm. The males average 2.7 mm in length and can be distinguished from the females by differences in size, genitalia, and terminal abdominal segments. Associated structures, such as sensory plates, components of female genital armature, which function in investigating a host cocoon prior to oviposition, are useful secondary characteristics.

The parasite is dark green with a metallic sheen. The tibiae and tarsi are amber and eyes, red. The basal segment of the antenna is green and flagellum, black. The flagellum occasionally exhibits a metallic green sheen. The cuticle of the adults of M. dentipes is smooth and shiny with fine setae concentrated in the corners of irregular geometric patterns formed by tiny reticulations of the cuticle. The setae and reticulations may be reduced or absent at points of articulation of segments.

Description of Immature Stages

No comprehensive description exists for all the immature stages of M. dentipes. Mertins (1967) and Mertins and Coppel (1971) described the egg and late instar, but not the other instars or the pupa. Morris et al. (1937) described the egg, the final instar, and the pupa, and illustrated these stages. They did not describe the early instars.

The egg is approximately elliptical with tapered ends, the adhesive end being more acutely tapered than the end bearing the micropyle (Morris et al. 1937). The shape of the egg has been likened to that of a banana (Mertins 1967; Mertins and Coppel 1971). It is about 0.7 by 0.2 mm, glossy white, and covered with symmetrical rows of minute spicules (Morris et al. 1937).

The last instar is white and somewhat crescent shaped (Morris et al. 1937). It can be distinguished from the larvae of all other parasites of sawfly cocoons by its smooth, densely setiferous integument.

Cephalic structures and spiracles of the last instar of sawfly parasites are diagnostic characters (Finlayson 1960a, 1960b, 1962; Mertins 1967; Mertins and Coppel 1971). Morris et al. (1937) have illustrated the cephalic structure of the last instar of M. dentipes. The spiracles of the last instar of M. dentipes were described and illustrated by Mertins (1967).

The pupa of M. dentipes was described by Morris et al. (1937) as being initially pale yellow, changing later to glossy black. The ovipositor, adhering closely to the dorsal surface of the pupa, enables easy differentiation of the females of M. dentipes from other cocoon parasites. These authors did not distinguish the male of M. dentipes from other parasites of sawfly cocoons. No cocoon is formed by M. dentipes (Mertins and Coppel 1971).

GEOGRAPHIC DISTRIBUTION AND ITS RELATION TO HOSTS

Generally, the distribution of *M. dentipes* depends on the presence of sawflies of the family Diprionidae, although other groups are represented as hosts (table 2). Wherever *M. dentipes* occurs, the hosts are most commonly *Diprion* spp. and *Neodiprion* spp. Other Hymenoptera, Diptera, and Lepidoptera are also parasitized, but far less frequently.

Table 2.--Recorded hosts of *Monodontomerus dentipes* (Dalman)

Hosts	Locality	Source
DIPTERA		
Tachinidae		
Arrhinomyia tragica L.[1]	France	Rosenburg 1934
HYMENOPTERA		
Braconidae		
Apanteles sp.	Poland	Thompson 1944
A. glomeratus L.[2]	France	Faure 1925, 1926; Thompson 1944
	Italy	Thompson 1944
Meteorus versicolor Wesmael[3]	Holland	de Fluiter 1933; Thompson 1944
Cynipidae	Sweden	Dalman 1820; Boheman 1833; Howard and Ashmead 1898
Diprionidae		
Diprion spp.	Poland	Mokrezecki 1933
	USA: New York	Viereck 1928; Gahan et al. 1928
D. frutetorum (Fabricius)	Canada: Ontario	Raizenne 1957; McGugan and Coppel 1962; Griffiths et al. 1971
	Czechoslovakia	Finlayson and Finlayson 1958a
D. hercyniae (Hartig)[4]	Canada: New Brunswick	Baird 1938
	Nova Scotia	Baird 1938
	Ontario	Finlayson and Reeks 1936; Baird 1937, 1939; Peck 1951; Finlayson 1960b; McGugan and Coppel 1962
	Quebec	Finlayson and Reeks 1936; Baird 1938; Briand 1949; McGugan and Coppel 1962
	China	Peck 1963
	Germany	Peck 1963
	Holland	Peck 1963
	Poland	Peck 1963
	USA: Maine	Procter 1938
	Vermont	Dowden 1938
D. pallidum (Klug)	Czechoslovakia	Morris et al. 1937

continued

See footnotes at end of table.

Table 2.--Recorded hosts of *Monodontomerus dentipes* (Dalman) (continued)

Hosts	Locality	Source
Diprion pini (L.)	Germany	Scheidter 1934; Thompson 1944
	Holland	Ritzema Bos 1919; Thompson 1944
	Poland	Sitowski 1929; Thompson 1944
	Sweden	Howard and Ashmead 1898
D. polytomum (Hartig)	Czechoslovakia	Kolubajiv 1934; Morris et al. 1937; Thompson 1944; Finlayson and Finlayson 1958b
	Germany	Morris et al. 1937
D. similis (Hartig)[6]	Europe (general)	Gahan 1941; Dowden 1949
	Canada: Ontario	Baird 1939; Gahan 1941; Bucher 1948; Dowden 1949; Raizenne 1957; Sippell et al. 1960; Finlayson 1962; McGugan and Coppel 1962
	Quebec	Baird 1938; Finlayson 1962; McGugan and Coppel 1962
	China	Peck 1963
	Germany	Thompson 1944
	Holland	Hartley 1923; Thompson 1944
	Hungary	Gahan 1941; Peck 1963
	Poland	Sitowski 1929; Finlayson and Finlayson 1958a
	Sweden	Howard and Ashmead 1898
	USA: Connecticut	Britton and Zappe 1918; Gahan 1941; Dowden 1949
	Maine	Gahan 1941; Procter 1946
	Michigan	Gahan 1941
	New Jersey	Weiss 1917a, 1917b, 1918; Hartley 1923; Gahan 1941; Dowden 1949, 1962
	New York	Gahan 1941
	Ohio	Gahan 1941
	Pennsylvania	Hartley 1923; Gahan 1941; Dowden 1949, 1962
	Wisconsin	Shenefelt and Benjamin 1955; Dowden 1962; Mertins 1967; Mertins and Coppel 1971
Neodiprion abietis (Harris)	Europe (general)	Baird 1944
	Canada: Ontario	McGugan and Coppel 1962
	New Brunswick	Baird 1944; McGugan and Coppel 1962
N. excitans Rohwer[8]	USA: Florida	Wilkinson, personal communication
N. lecontei (Fitch)[8]	USA: Florida	Wilkinson 1969
N. pinetum (Norton)	Canada: Ontario	Raizenne 1957; McGugan and Coppel 1962
	Manitoba	Baird 1941; McGugan and Coppel 1962

continued

See footnotes at end of table.

Table 2.--Recorded hosts of *Monodontomerus dentipes* (Dalman) (continued)

Hosts	Locality	Source
N. pratti banksianae Rohwer	Canada: Ontario	Baird 1941
N. p. pratti Rohwer[8]	USA: Virginia	Morris 1971
N. swainei Middleton	USA: Wisconsin	Becker and Benjamin 1964
Eulophidae		
Dahlbominus fuscipennis Zetterstedt[6]	USA: Wisconsin	Mertins 1967; Mertins and Coppel 1971
Tetrastichus xanthopus (Ratzeburg)[7]	Austria	Seitner 1927
Ichneumonidae		
Exenterus amictorius (Panzer)[6]	USA: Wisconsin	Mertins 1967; Mertins and Coppel 1971
Itoplectis conquisitor Say[6]	USA: Wisconsin	Mertins 1967; Mertins and Coppel 1971
Pimpla sp.[7]	Austria	Seitner 1927
Therion giganteum (Gravenhorst)[7]	Austria	Seitner 1927
Theronia atalanta (Poda)[7]	Austria	Seitner 1927
Vespidae		
Ancistrocerus tigris tigris (Saussure)[8]	USA: Wisconsin	Coppel 1960
LEPIDOPTERA		
Liparidae		
Euproctis chrysorrhoea (L.)[9]	Sweden	Howard and Ashmead 1898
Lymantriidae		
Dendrolimus pini (L.)[7]	Austria	Seitner 1916, 1927; Hartley 1923
	Germany	Thompson 1944
Nygmia phaeorrhoea (Donovan)[10]	USA: Idaho	Peck 1963
Orgyia pseudotsugata (McDonough)[10, 11]	USA: Idaho	Bedard 1938
Stilpnotia salicis L.[3]	Holland	de Fluiter 1933
Porthetria dispar (L.)	New England	Burgess 1915
Pieridae		
Pieris brassicae L.[2]	France	Faure 1926

continued

See footnotes at end of table.

Table 2.--Recorded hosts of *Monodontomerus dentipes* (Dalman) (continued)

Hosts	Locality	Source
Tortricidae		
Cydia pomonella L.[1]	France	Rosenburg 1934
Tortrix viridana (Girard)	Sweden	Howard and Ashmead 1898
Zygaenidae		
Zygaena filipendulae L.	Sweden	Howard and Ashmead 1898
Z. occitanica de Villers	France	Hartley 1923

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[1] *M. dentipes* is hyperparasitic on *Cydia pomonella* L. through *A. tragica*.

[2] *M. dentipes* is hyperparasitic on *Pieris brassicae* L. through *A. glomeratus*.

[3] *M. dentipes* is hyperparasitic on *Stilpnotia salicis* L. through *M. versicolor* (de Fluiter 1933).

[4] Early North American references to *D. hercyniae* mistakenly identified it as *D. polytomum* (McGugan and Coppel 1962).

[5] *M. dentipes* is both a primary parasite and a hyperparasite of *D. similis*. *D. similis* is a secondary host through *D. fuscipennis*, *E. amictorius*, and *I. conquisitor*.

[6] *M. dentipes* was released against these hosts in a biological control effort of the USDA Forest Service. No recoveries have been made to date.

[7] *M. dentipes* is hyperparasitic on *Dendrolimus pini* through these species (Seitner 1927).

[8] *M. dentipes* was reported as a primary parasite of *A. tigris tigris* inhabiting empty cocoons of *D. similis*.

[9] As *Porthesia chrysorrhoea* L.

[10] Peck (1963) believes these hosts indicate *M. aereus*, not *M. dentipes*.

[11] As *Hemerocampa pseudotsugata*.

M. dentipes is native to the Palearctic region of the world and distributed exclusively in the Holarctic region (table 3). Although *M. dentipes* is found throughout the Palearctic region, only a single locality record exists for China (Gahan 1941). *M. dentipes* has been reported throughout northern and central Europe. Records from France and Austria list nonsawfly hosts exclusively. Peck (1963) believed these hosts suggested the parasite was identified incorrectly and was *M. aereus* Walker, not *M. dentipes*. In Europe, *Diprion pini* (L.) and *D. polytomum* (Hartig) are the most frequently parasitized hosts.

In the Nearctic region, *M. dentipes* occurs in the United States and Canada, primarily east of the Great Plains. *M. dentipes* was accidentally introduced into the United States as a parasite of the sawfly, *D. similis*, which subsequently became the most frequently attacked host in this country. *M. dentipes* was first reported in Connecticut around 1910 (Britton 1915, Britton and Zappe 1918) and shortly after in New Jersey (Weiss 1917a, 1917b, 1918; Hartley 1923; Gahan 1941; Dowden 1949). By 1922, *D. similis* was effectively parasitized by *M. dentipes* in a minor infestation near Philadelphia, Pennsylvania (Hartley 1923), which marked the southernmost extension of the parasite's distribution at that time. In later years, the parasite was reported on the same host in Maine, Michigan, Ohio, and Wisconsin, and on other *Diprion* spp. in Maine, Vermont, and New York (table 4). West of Wisconsin, a single record exists of *M. dentipes*, and two lepidopterous hosts are listed (Bedard 1938).

Table 3.--Palearctic distribution of *Monodontomerus dentipes* (Dalman)

Continent and country	Hosts	Source
ASIA		
China	*Diprion hercyniae* (Hartig)	Peck 1963
	D. similis (Hartig)	Peck 1963
EUROPE		
(general)	*Diprion pini* (L.)	Steffan 1952
	D. similis	Gahan 1941; Dowden 1949
	D. sertifer Geoffroy	Steffan 1952
Austria	*Dendrolimus pini* L.[1]	Seitner 1916, 1927
	Tetrastichus xanthopus (Ratzeburg)[1]	Seitner 1927
	Pimpla sp.[1]	Seitner 1927
	Therion giganteum (Gravenhorst)[1]	Seitner 1927
	Theronia atalanta (Poda)[1]	Seitner 1927
	Rhogas sp.[1]	Seitner 1927
Czechoslovakia	*D. frutetorum* (F.)	Finlayson and Finlayson 1958b
	D. palladium Klug	Morris et al. 1937
	D. polytomum (Hartig)	Kolubajiv 1934; Morris et al. 1937; Thompson 1944; Finlayson and Finlayson 1958a
France	*Apanteles glomeratus* L.[2]	Faure 1925, 1926; Thompson 1944
	Arrhinomyia tragica L.[3]	Rosenburg 1934
	Cydia pomonella L.[3]	Rosenburg 1934
	Pieris brassicae L.[3]	Faure 1925
	Zygaena occitanica de Villers	Hartley 1923
Germany	*D. hercyniae*	Peck 1963
	Diprion pini	Scheidter 1934; Thompson 1944
	D. polytomum	Morris et al. 1937
Holland	*D. hercyniae*	Peck 1963
	D. similis	Hartley 1923; Thompson 1944
	Diprion pini	Ritzema Bos 1919; Thompson 1944
	Meteorus versicolor Wesmael[4]	de Fluiter 1933; Thompson 1944
	Stilpnotia salicis L.	de Fluiter 1933

continued

See footnotes at end of table.

Table 3.--Palearctic distribution of *Monodontomerus dentipes* (Dalman) (continued)

Continent and country	Hosts	Source
Hungary	*D. similis*	Gahan 1941; Peck 1963
Italy	*A. glomeratus*	Thompson 1944
Poland	*Apanteles* spp.	Thompson 1944
	A. glomeratus[2]	Mokrezecki 1933
	Diprion spp.	Mokrezecki 1933
	D. hercyniae	Peck 1963
	Diprion pini	Sitowski 1929; Thompson 1944
	D. similis	Sitowski 1929; Finlayson and Finlayson 1958b
	P. brassicae	Mokrezecki 1933
Sweden	Cynipid wasps	Dalman 1820; Boheman 1833; Howard and Ashmead 1898
	Diprion pini[5]	Howard and Ashmead 1898
	D. similis[6]	Howard and Ashmead 1898
	Euproctis chrysorrhoea L.[7]	Howard and Ashmead 1898
	Tortrix viridana (Giraud)	Howard and Ashmead 1898
	Zygaena filipendulae L.	Howard and Ashmead 1898

[1] *M. dentipes* is a hyperparasite of *Dendrolimus pini* L. through these species (Seitner 1927).
[2] *M. dentipes* is a hyperparasite of *P. brassicae* through *A. glomeratus*.
[3] *M. dentipes* is a hyperparasite of *C. pomonella* through *A. tragica*.
[4] *M. dentipes* is a hyperparasite of *S. salicis* through *M. versicolor* (de Fluiter 1933).
[5] As *Lophyrus pini* L.
[6] As *Lophyrus similis* Hartig.
[7] As *Porthesia chrysorrhoea* L.

Table 4.--Nearctic distribution of *Monodontomerus dentipes* (Dalman)

Locality	Hosts	Source
NORTH AMERICA		
(general)	*Diprion* spp.	Peck 1951
	D. hercyniae (Hartig)	Peck 1951
	D. similis (Hartig)	Peck 1951
	Diptera	Peck 1951
	Orgyia pseudotsugata (McDonnough)[1]	Peck 1951
	Petalodes unicolor (Wesmael)	Peck 1951
	Porthetria dispar L.	Burgess 1915
Canada		
(general)	*D. similis*	McGugan and Coppel 1962
	Neodiprion sertifer (Geoffroy)	Finlayson 1960a
	N. virginianus complex	McGugan and Coppel 1962
Manitoba	*N. pratti banksianae* Rohwer	Baird 1941; McGugan and Coppel 1962
New Brunswick	*D. hercyniae*[a]	Baird 1938, 1939
	N. abietis (Harris)	Baird 1944; McGugan and Coppel 1962
Nova Scotia	*D. hercyniae*	Baird 1938
Ontario	*D. frutetorum* (F.)	Raizenne 1957; McGugan and Coppel 1962; Griffiths et al. 1971
	D. hercyniae	Finlayson and Reeks 1936; Baird 1937, 1939; Peck 1951; Finlayson 1960b; McGugan and Coppel 1962
	D. similis	Baird 1939; Gahan 1941; Bucher 1948; Dowden 1949; Raizenne 1957; Sippell et al. 1960; Finlayson 1962; McGugan and Coppel 1962
	N. abietis	McGugan and Coppel 1962
	N. pinetum (Norton)	Raizenne 1957; McGugan and Coppel 1962
	N. pratti banksianae	Baird 1941
	N. sertifer	Finlayson 1960a; McGugan and Coppel 1962; Lyons 1964; Griffiths et al. 1971
	Rhyacionia buoliana (Schiffermüller)	Watson and Arthur 1959; McGugan and Coppel 1962
Quebec	*D. hercyniae*[a]	Finlayson and Reeks 1936; Baird 1938, 1939; Briand 1949; McGugan and Coppel 1962
	D. similis	Baird 1938, 1939; Finlayson 1962; McGugan and Coppel 1962

continued

See footnotes at end of table.

Table 4.--Nearctic distribution of *Monodontomerus dentipes* (Dalman) (continued)

Locality	Hosts	Source
U.S.A.		
Connecticut	*D. similis*	Britton and Zappe 1918; Britton 1920; Gahan 1941; Dowden 1949
Florida	*N. lecontei* (Fitch)[3]	Wilkinson 1969
Idaho	*O. pseudotsuga*[1]	Bedard 1938
	Nygmia phaeorrhoea (Donovan)	Bedard 1938
Maine	*D. hercyniae*	Procter 1938
	D. similis	Gahan 1941; Procter 1946
Michigan	*D. similis*	Gahan 1941
New Jersey	*D. similis*	Weiss 1917a, 1917b, 1918; Hartley 1923; Gahan 1941; Dowden 1949, 1962
New York	*Diprion* spp.	Viereck 1928; Gahan et al. 1928
	D. similis	Gahan 1941
Ohio	*D. similis*	Gahan 1941
Pennsylvania	*D. similis*	Hartley 1923; Gahan 1941; Dowden 1949, 1962
Vermont	*D. hercyniae*	Dowden 1962
Virginia	*N. pratti pratti* Rohwer[3]	Morris 1971
Wisconsin	*Ancistrocerus tigris tigris* (Saussure)[4]	Coppel 1960
	D. similis	Shenefelt and Benjamin 1955; Dowden 1962; Mertins 1967; Mertins and Coppel 1971
	N. swainei Middleton	Becker and Benjamin 1964

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[1] As *Hemerocampa pseudotsugata*.

[2] Early North American references to *D. hercyniae* mistakenly identified it as *D. polytomum* (McGugan and Coppel 1962).

[3] *M. dentipes* was released against these hosts in 1969-1970 through the biological control program of the USDA Forest Service. It has not been recovered to date.

[4] *M. dentipes* was listed as a primary parasite of *A. tigris tigris*, common inhabitants of cocoons of *D. similis*.

In Canada, *M. dentipes* has been released against pine sawflies in biological control programs in Ontario, Quebec, Manitoba, Nova Scotia, New Brunswick, and Prince Edward Island (table 4). In Ontario, *D. similis* is common and more frequently attacked than any other potential host. However, in Quebec and the Maritime Provinces, *D. hercyniae* is the most abundant sawfly and the most heavily parasitized.

Generally, in the Nearctic region, *M. dentipes* is concentrated in coastal regions. The distribution of the parasite extends along the Atlantic coast from Pennsylvania to Quebec, and westward along the Great Lakes to Wisconsin and Manitoba. Recent releases against sawflies in the southeastern United States (Wilkinson 1969; Morris 1971) have provided an opportunity for the range of *M. dentipes* to be extended southward as far as Florida, however, establishment has not yet been determined.

HOSTS

Included among the known hosts of M. dentipes are six families of Hymenoptera, one family of Diptera, and five families of Lepidoptera (table 2). Among the various families that have been reported are: Diprionidae, Braconidae, Ichneumonidae, Eulophidae, Vespidae, and Cynipidae in the order Hymenoptera; Tachinidae in the order Diptera; and Liparidae, Lymantriidae, Zygaenidae, Tortricidae, and Pieridae in the order Lepidoptera.

Hymenoptera of the family Diprionidae are the predominant hosts throughout the distribution of M. dentipes. Of this family, six species of Diprion and five species of Neodiprion, with two additional Neodiprion spp. as potential hosts, are parasitized, the former genus being by far the more common host. In the Palearctic region, M. dentipes attacks N. sertifer (Geoffroy) and six species of Diprion; only the genus Diprion is recorded as a host in Asia. D. hercyniae and D. similis have been reported as hosts of M. dentipes in China (Peck 1963). The principal hosts of M. dentipes in Europe, where the parasite is more common, appear to be Diprion pini and D. polytomum (table 3). D. similis and D. hercyniae have also been reported, but less frequently. D. frutetorum (F.) and D. pallidum Klug have been listed as hosts by Finlayson and Finlayson (1958a) and Morris et al. (1937), respectively.

In the Nearctic region, the hosts of M. dentipes include three Diprion species and five Neodiprion species (table 4). Here the host complex of M. dentipes differs from that of Europe in that D. polytomum, Diprion pini, and D. pallidum are absent.[2] N. pinetum (Norton), N. pratti pratti Rohwer, N. p. banksianae Rohwer, and N. swainei Middleton, in addition to the single Neodiprion sp. attacked in Europe, N. sertifer, are attacked. N. excitans Rohwer and N. lecontei (Fitch) are potential hosts in the United States. In North America, as in the Palearctic region, Diprion spp. are the principal hosts. D. similis and D. hercyniae are the most frequently parasitized hosts in Canada. D. similis predominates in southern Ontario and D. hercyniae, in Quebec and the Maritime Provinces. Occasionally, M. dentipes parasitizes D. frutetorum, N. pinetum, N. sertifer, and the N. virginianus complex in Canada (table 4). In contrast, D. similis is almost the exclusive host of M. dentipes in the United States, although the parasite has been reported infrequently on D. hercyniae and N. sertifer as well (table 4).

Throughout Europe and the Nearctic region, M. dentipes has been reported on Lepidoptera and Hymenoptera other than Diprionidae (tables 3 and 4). Collectively, records of nonsawfly hosts are insignificant when compared numerically to records of sawfly hosts. However, they are an important factor in the host relationships of M. dentipes. M. dentipes has been recorded on three species of Braconidae and an unspecified species of Ichneumonidae. Similarly, only a few cases of M. dentipes parasitizing cynipid wasps have been reported from Europe. In addition, there are two North American records of the parasite on Tachinidae (Burgess 1915; Peck 1951). Many of the records of M. dentipes on nonsawfly Hymenoptera and Tachinidae refer to M. dentipes as a hyperparasite of a pine sawfly or lepidopterous host. The only records of M. dentipes parasitizing Lepidoptera in North America are from Idaho, where it was reported by Bedard (1938) from Nygmia phaeorrhoea (Donovan) and Orgyia pseudotsugata (McDonnough). Dendrolimus pini L. is the only lepidopterous host from Europe which has been parasitized widely by M. dentipes.

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[2] Prior to 1941, when D. hercyniae was correctly identified by Smith (1941) as the species involved in Canadian infestations, populations of this sawfly were believed to be conspecific with those of the European species D. polytomum. As such, several early sources incorrectly refer to D. hercyniae as D. polytomum (McGugan and Coppel 1962).

Life History and Host Relationships

Morris et al. (1937) and Mertins (1967) are the only authors who have touched on a variety of topics related to the life cycle of the parasite, M. dentipes. In their studies, they included mating and oviposition, hatching of the eggs, maturation of larvae, pupation, emergence from the host cocoon, longevity of adults, and host relationships of M. dentipes. Mertins and Coppel (1971) revised the material pertaining to host relationships that Mertins (1967) had provided. They omitted much of the detailed information about M. dentipes that Mertins (1967) had included.

The stages in the life cycle of M. dentipes were described initially by Morris et al. (1937). These workers were unable to rear M. dentipes in the laboratory so their description was based on observations in the field and on field-collected material. The female of M. dentipes usually laid five or six (maximum, 15) eggs in a single host cocoon. The larvae fed externally on the prepupa of the sawfly host, devouring it completely. The larvae matured after 3 to 4 weeks. M. dentipes overwintered as prepupae, or, if weather were favorable, developed immediately into pupae. In April, when overwintering individuals pupated, the pupal stage lasted 3 weeks. During the summer, when other individuals pupated, the pupal stage was shorter. Four or five (maximum, 12) adults of M. dentipes emerged per host cocoon. Emergence of the first generation of adults occurred in May, although adults were found in the field into September. A full month elapsed between the emergence of the first and last insects from one cocoon.

Mertins' (1967) observations agree essentially with those of Morris et al. (1937). However, Mertins provided additional information about the Wisconsin parasites of D. similis. He reared M. dentipes from field collected cocoons of D. similis and studied the behavior, oviposition, and longevity of the parasite under unspecified laboratory conditions. M. dentipes took 28 days to develop from eggs to adults. Larvae hatched within 3 days of oviposition, fed on the host for 8 days, then were quiescent for 3 additional days before defecating. Afterwards, the larvae tended to position themselves in a single layer around the host cadaver and cocoon walls, all facing in the same direction. They pupated within 2 days after defecation and emerged 9 to 13 days later. No cocoons were formed. Mean emergence from 100 parasitized cocoons was 7.74 (range, 1-22). The sex ratio was 1.16 females per male. Males emerged up to a day before the females. A male would cut an exit hole in the host cocoon, emerge, and wait near the opening for a female to emerge. Then, beating his wings intermittently, he would follow her, climb on her back, tap her head with his antennae, and eventually attempt copulation. Males usually remounted until successful. Copulation lasted 15 to 20 seconds. Adult males lived 9.8 days while females lived 30.6 days in the laboratory when fed sugar water.

The host relationships of M. dentipes are often complex and potentially confusing since the range of its activities spans that of a primary parasite to possibly that of a semi-scavenger. On its most important hosts, the pine sawflies, it can act directly as a primary parasite, or indirectly as a hyperparasite and Coppel (1960) reported M. dentipes as a primary parasite of the solitary wasp, Ancistrocerus tigris tigris (Saussure), inhabiting empty cocoons of D. similis. In some circumstances, it can even compete successfully in a multiparasitic situation.

Morris et al. (1937) reported that *M. dentipes* was always a primary parasite on *D. polytomum*. Mertins (1967) reared *M. dentipes* most often as a primary parasite from his Wisconsin collections of *D. similis*. However, from a group of 100 parasitized *D. similis* cocoons he examined, *M. dentipes* was at least associated with another parasite species in seven cases. Under such circumstances, *M. dentipes* attacked *Exenterus amictorius* (Panzer), *Itoplectis conquisitor* (Say), and *Dahlbominus fuscipennis* (Zetterstedt) (Mertins 1967). Mertins and Coppel (1971) extended the list of primary parasites of *D. similis* attacked by *M. dentipes* to include *Diplostichus lophyri* (Townsend). The relationship of *M. dentipes* to the parasites listed was thought to be facultative.

Mertins (1967) also reported that *M. dentipes* could compete successfully in a multiparasitic relationship on *D. similis*. During the summer months, adults of *M. dentipes* emerge constantly with the females ovipositing in new sawfly cocoons, so that the parasitism of sawflies is cumulative as the summer progresses (Morris et al. 1937). If the population of *M. dentipes* increases sufficiently by the time the second generation of sawflies forms cocoons, *M. dentipes* may attack sawfly cocoons already parasitized by other individuals of *M. dentipes* or by some other species of parasite (Mertins 1967). Secondary parasitism, multiparasitism, or superparasitism may occur. *M. dentipes* usually survives in either case. Mertins (1967) seldom found dead *M. dentipes* in cocoons that had also been attacked by another species of parasite. In one instance, Mertins observed both *Eupelmella vesicularis* (Retzius) and *M. dentipes* emerging from the same host cocoon. In addition, Mertins (1967) and Mertins and Coppel (1971) reared *M. dentipes* from the same host cocoon with *E. amictorius*, *E. vesicularis*, *Gelis tenellus* (Say), *Habrocytus thyridopterigis* Howard, and *Amblymerus verditer* (Norton). However, this was a rarity.

In addition, *M. dentipes* may be a semi-scavenger. Mertins (1967) reported, in his work on the Wisconsin parasites of *D. similis*, that *M. dentipes* developed once on the remains of a sawfly left after the development of an ichneumonid parasite. He was unable to discern whether *M. dentipes* had attacked the sawfly cocoon during or after the development of the ichneumonid. Since the time of parasitism by *M. dentipes* was the crucial factor, he was unable to eliminate the possibility that the relationship had been multiparasitic originally.

M. dentipes is versatile in the host relationships it can assume. Regardless of what that relationship proves to be, the extent to which the females of *M. dentipes* can successfully attack pine sawflies is determined by the location in the soil or duff where the host sawfly forms its cocoon. For instance, *D. polytomum*, *D. similis*, and *D. hercyniae* are heavily parasitized by *M. dentipes*. They occur in the same areas with *N. sertifer* in Europe and North America, but *N. sertifer* is seldom attacked on either continent. In the first record of *M. dentipes* on *N. sertifer* in Canada, only one host cocoon produced the parasites (Finlayson 1960b) and subsequent reports are similarly meager (Griffiths et al. 1971; Lyons 1964).

M. dentipes was not effective against *N. sertifer* because the parasite could not reach the cocoons of *N. sertifer* in the mineral soil (Lyons 1964). Lyons (1964) reported that fewer than 3 percent of the *N. sertifer* at Chatsworth, Ontario, cocooned above the mineral soil, although a conflicting report exists (Morris and Cameron 1935). In contrast, *D. polytomum*, *D. hercyniae*, and *D. similis* all cocoon above mineral soil; *D. polytomum* and *D. similis*, on the host tree and nearby shrubs; and *D. hercyniae*, in the surface litter (McGugan and Coppel 1962).

The extent to which M. dentipes parasitizes a given host may also depend on physical and physiological characteristics of the host cocoon or host prepupa. The parasite is able to distinguish between the larch sawfly, Pristiphora erichsonii (Hartig), which is not known to be a host of M. dentipes, and N. lecontei, which is successfully parasitized by M. dentipes in the laboratory (Drooz and Fedde 1972). The ability of M. dentipes to differentiate between these hosts, which are very similar in appearance, is evident at both the cocoon and prepupal levels.

SUMMARY AND SUGGESTIONS FOR FURTHER STUDY

Most publications referring to M. dentipes pertained primarily to its hosts or distribution until 1937, when Morris et al. described the parasite along with others of D. polytomum in Europe. When the importance of M. dentipes in the control of D. similis in the United States and Canada was realized, the number of host and locality records of this insect mushroomed. Mertins (1967) recently made the second major contribution to knowledge about the life history and host relationships of M. dentipes.

Since M. dentipes is potentially useful for biological control of Neodiprion spp., which cocoon above ground, in the southeastern United States, additional studies are needed on the parasite's ability to function in such a capacity. There is a need for more understanding of the physiological responses to environmental factors for this parasite, as well as of natural food of the adults and the parasite's behavior and ability to select hosts. If M. dentipes is to be employed successfully against sawflies of the genus Neodiprion, much more about the biology of the parasite must be understood.

LITERATURE CITED

Baird, A. B.
1937. Biological control of the spruce sawfly Diprion polytomum Hartig. Pulp Pap. Mag. Can. 38: 311-312, 314-315.

Baird, A. B.
1938. Parasite and predator liberations in 1937. Can. Insect Pest Rev. 16: 77-154.

Baird, A. B.
1939. Parasite and predator liberations in 1938. Can. Insect Pest Rev. 17: 101-128.

Baird, A. B.
1941. Parasite and predator liberations in 1940. Can. Insect Pest Rev. 19: 94-125.

Baird, A. B.
1944. Parasite and predator liberations in 1943. Can. Insect Pest Rev. 22: 117-138.

Becker, G. C., Jr., and Benjamin, D. M.
1964. Notes on insect parasites and predators of the Swaine jack-pine sawfly in Wisconsin. J. Econ. Entomol. 57: 355-357.

Bedard, W. D.
1938. An annotated list of the insect fauna of Douglas fir (Pseudotsuga mucronata Rafinesque) in the northern Rocky Mountain region. Can. Entomol. 70: 196.

Boheman, C. H.
1833. Skandinaviska Pteromaliner. Kongl. Sven. Vetensk. Acad. Handl., p. 329-380.

Briand, L. J.
1949. Spruce sawfly parasite investigations. Park Reserve, St. Alexandre, Kamouraska, Quebec. Annu. Rep. Quebec Soc. Prot. Plants 30: 54-59.

Britton, W. E.
1915. A destructive pine sawfly introduced from Europe. *Diprion* (*Lophyrus*) *simile* Hartig. J. Econ. Entomol. 8: 379-382.

Britton, W. E.
1920. Check-list of the insects of Connecticut. Conn. State Geol. & Nat. Hist. Surv. Bull. 31, 397 p.

Britton, W. E., and Zappe, M. P.
1918. The imported pine sawfly *Diprion* (*Lophyrus*) *simile* Hartig. 17th Report of the State Entomologist of Connecticut for the year 1917. Conn. Agric. Exp. Stn. Bull. 203: 273-290.

Bucher, G. E.
1948. The anatomy of *Monodontomerus dentipes* Boh., an entomophagous Chalcid. Can. J. Res. 26: 230-281.

Burgess, A. F.
1915. Report on the gipsy moth work in New England. U.S. Dep. Agric., Agric. Bull. 204, 32 p.

Burks, B. D.
1963. The Provancher species of Chalcidoidea (Hymenoptera). Can. Entomol. 95: 1254-1263.

Coppel, H. C.
1960. Empty cocoons of the introduced pine sawfly, *Diprion similis*, as habitat niches for arthropods. Ann. Entomol. Soc. Am. 53: 847-848.

Dalman, J. V.
1820. Försök till Uppställning af Insect-familjen Pteromalini, i synnerhet med afseende pa de i Sverige funne Arter. Kongl. Sven. Vetensk. Acad. Handl. 41: 123-182.

Dowden, P. B.
1949. Bees, wasps, ants and parasites, p. 591-636. *In* F. C. Craighead [ed.], Insect enemies of eastern forests. U.S. Dep. Agric., Misc. Publ. 657, 679 p.

Dowden, P. B.
1962. Parasites and predators of forest insects liberated in the United States through 1960. U.S. Dep. Agric., Agric. Handb. 226, 70 p.

Drooz, A. T., and Fedde, V. H.
1972. Discriminate host selection by *Monodontomerus dentipes*. Environ. Entomol. 1: 522-523.

Faure, J. C.
1925. Sur la multiplicité des parasites de l'*Apanteles glomeratus* L. C. R. Soc. Biol. 93: 524-526. (Abstr.) Rev. Appl. Entomol. Ser. A, 13: 460.

Faure, J. C.
1926. Contibution á l'étude d'un complexe biologique: la Piéride du chou (*Piéris brassicae*, L.) et ses parasites hyménoptéres. (Abstr.) Rev. Appl. Entomol. Ser. A, 14: 516.

Finlayson, L. R., and Finlayson, T.
1958a. Notes on the parasites of Diprionidae in Europe and Japan and their establishment in Canada on *Diprion hercyniae* (Htg.) (Hymenoptera: Diprionidae). Can. Entomol. 90: 557-563.

Finlayson, L. R., and Finlayson, T.
1958b. Notes on parasitism of a spruce sawfly, *Diprion polytomum* (Htg.) (Hymenoptera: Diprionidae) in Czechoslovakia and Scandinavia. Can. Entomol. 90: 584-589.

Finlayson, L. R., and Reeks, W. A.
1936. Notes on the introduction of *Diprion* parasites to Canada. Can. Entomol. 68: 160-166.

Finlayson, T.
1960a. Taxonomy of cocoons and puparia, and their contents, of Canadian parasites of Neodiprion sertifer (Geoff.) (Hymenoptera: Diprionidae). Can. Entomol. 92: 20-47.

Finlayson, T.
1960b. Taxonomy of cocoons and puparia, and their contents, of Canadian parasites of Diprion hercyniae (Htg.) (Hymenoptera: Diprionidae). Can. Entomol. 92: 922-941.

Finlayson, T.
1962. Taxonomy of cocoons and puparia, and their contents, of Canadian parasites of Diprion similis (Htg.) (Hymenoptera: Diprionidae). Can. Entomol. 94: 271-282.

Finlayson, T.
1963. Taxonomy of cocoons and puparia, and their contents, of Canadian parasites of some native Diprionidae (Hymenoptera). Can. Entomol. 95: 475-507.

Fluiter, H. J. de
1933. 1. Voorloopige mededeeling van enkele resultaten, verkregen bij een onderzoek, ingestald naar de parasieten fauna tigdens eene gradatie van Stilpnotia salicis (L.) te Wageningen. 2. Korte mededeeling over de biologie van Microcryptus subguttatus Grav., het belangrijkste parasietische hymenopteron van Diprion pini (L.). [1. A preliminary communication on some results obtained in an investigation on the parasite fauna of S. salicis during an outbreak of the latter at Wageningen. 2. A brief communication on the biology of M. subguttatus, the most important hymenopterous parasite of D. pini.] Tijschr. Entomol. 76: 8-11. (Abstr.) Rev. Appl. Entomol. Ser. A, 21: 381.

Gahan, A. B.
1941. A revision of the chalcid-flies of the genus Monodontomerus in the United States National Museum. U.S. Natl. Mus. Proc. 90: 461-482.

Gahan, A. B., Crosby, C. R., and Leonard, M. D.
1928. Superfamily Chalcidoidea, p. 975-985. In M. D. Leonard [ed.], A list of the insects of New York with a list of the spiders and allied groups. N.Y. Agric. Exp. Stn. Mem. 101.

Griffiths, K. J., Rose, A. H., and Bird, F. T.
1971. Neodiprion sertifer (Geoffroy), European pine sawfly (Hymenoptera: Diprionidae), p. 150-162. In W. A. Reeks [ed.], Part III Biological control of forest insect pests in Canada 1959-1968. Biological control programmes against insects and weeds in Canada 1959-1968. Commonw. Inst. Biol. Control, Agric. Bur. Tech. Commun. 4, Trinidad.

Hartley, E. A.
1923. Parasitism of the European pine sawfly, Diprion (Lophyrus) simile Hartig, Hymenoptera, Tenthredinidae, in Pennsylvania. J. Econ. Entomol. 16: 386-388.

Howard, L. O., and Ashmead, W. H.
1898. Chalcidae et Proctotrupidae, Vol. V. In C. G. de Dalla Torre [ed.], Catalogus Hymenopterorum huscusque descriptorum systematicus et synonymicus. Engelmann, Lepipsig, 598 p.

Kolubajiv, I. S.
1934. Die Ergebnisse der Züchtung von Parasitischen Insektenarten aus ihren Wirten in der Staatlichen Versuchsanstalt in den J.J. 1929-1933. Acta Soc. Entomol. Cechoslov. 31: 59-68, 113-120, 155-163. (Abstr.) Rev. Appl. Entomol. Ser. A, 23: 229.

Lyons, L. A.
1964. The European pine sawfly, Neodiprion sertifer (Geoff.) (Hymenoptera: Diprionidae). A review with emphasis on studies in Ontario. Entomol. Soc. Ontario Proc. 94: 5-37.

McGugan, B. M., and Coppel, H. C.
1962. Biological control of forest insects, 1910-1958, p. 35-216. In A review of the biological control attempts against insects and weeds in Canada. Commonw. Inst. Biol. Control Tech. Commun. 2, Trinidad.

Mertins, J. W.
1967. The insect parasites of the introduced pine sawfly, Diprion similis (Hartig) (Hymenoptera: Diprionidae), in Wisconsin. Master's Thesis, Univ. Wisc., 119 p.

Mertins, J. W., and Coppel, H. C.
1971. The insect parasites of the introduced pine sawfly, Diprion similis (Hartig) (Hymenoptera: Diprionidae), in Wisconsin, with keys to the adults and mature larval remains. Wisc. Acad. Sci., Arts, & Lett. 59: 127-168.

Mokrezecki, Z.
1933. Die in den Förstschladingen lebenden Parasiten des 1. and 2. Grades aus der Gruppe der Chalcidoidea. [Chalcidoid parasites and hyperparasites of forest pests.] Pol. Pismo Entomol. 12: 143-144. (Abstr.) Rev. Appl. Entomol. Ser. A, 22: 495.

Morris, C. L.
1971. Forest pest survey report for September, 1971. Va. Div. For., 5 p.

Morris, K. R. S., and Cameron, E.
1935. The biology of Microplectron fuscipennis Zett. (Chalcididae) a parasite of the pine sawfly (Diprion sertifer Geoffr.). Bull. Entomol. Res. 26: 407-418.

Morris, K, R. S., Cameron, E., and Jepson, W. F.
1937. The insect parasites of the spruce sawfly (Diprion polytomum Htg.) in Europe. Bull. Entomol. Res. 28: 341-393.

Peck, O.
1951. Superfamily Chalcidoidea, p. 410-594. In C. F. W. Muesebeck, K. V. Krombein, and H. K. Townes [eds.], Hymenoptera of America north of Mexico - Synoptic Catalog. U.S. Dep. Agric., Agric. Monogr. 2, 1,420 p.

Peck, O.
1963. A catalogue of the Nearctic Chalcidoidea (Insecta: Hymenoptera). Can. Entomol. Suppl. 30, 1,092 p.

Procter, W.
1938. Biological survey of the Mount Desert Region. Part VI. Insect fauna. 423 p. Philadelphia: The Wistar Inst. Anat. & Biol.

Procter, W.
1946. Biological survey of the Mount Desert Region. Part VII. Insect fauna. 483 p. Philadelphia: The Wistar Inst. Anat. & Biol.

Raizenne, H.
1957. Forest sawflies of southern Ontario and their parasites. Can. Dep. Agric. Publ. 1009.

Ritzema Bos, J.
1919. Veislag over Onderzoekingen, gedaan in-en over Inlichtingen, gegeven van het Instituiit voor Phytopathologie te Wageningen, in het Yaar, 1915. Meded. Landbouwhoogesch., Wageningen 17: 105-157. (Abstr.) Rev. Appl. Entomol. Ser. A, 7: 443.

Rosenburg, H. T.
1934. The biology and distribution in France of the larval parasites of Cydia pomonella L. Bull. Entomol. Res. 25: 201-256.

Scheidter, F.
1934. Forstentomologische Beitrage 14-38. [Contributions to forest entomology, 14-38.] Z. Pflanzen Kr. (Pflanzenpathol.) Pflantzenschutz 44: 223-226, 386-423, 497-525. (Abstr.) Rev. Appl. Entomol. Ser. A, 22: 720.

Seitner, M.
1916. Bombyx pini injurious to pine trees in Austria. Centralbl. Gesamte Forstwes. 41: 161-173. (Abstr.) Int. Rev. Sci. & Pract. Agric. 7: 173-175.

Seitner, M.
1927. Aus der Praxis der Kiefernspinnerbekampfung. [The control of Dendrolimus pini.] Z. Angew. Entomol. 12: 438-445. (Abstr.) Rev. Appl. Entomol. Ser. A, 15: 384.

Shenefelt, R. D., and Benjamin, D. M.
1955. Insects of Wisconsin forests. Wisc. Coll. Agric. Ext. Serv. Circ. 500, 110 p.

Sippell, W. L., MacDonald, J. E., and Rose, A. H.
1960. Forest insect survey, Province of Ontario. Can. Dep. Agric. Annu. Rep., For. Insect Dis. Surv. (1959): 44-62.

Sitowski, L.
1929. Do biologji pasorzytow borecznika (Lophyrus Latr.). Czesc. II. [On the biology of the parasites of Diprion. Part II.] Prac. Komis. mat.-prz. Poznansk. Towarz. Prz. Nauk Ser. B, 5: 1-8. (Abstr.) Rev. Appl. Entomol. Ser. A, 17: 643-644.

Smith, S. G.
1941. A new form of spruce sawfly identified by means of its cytology and parthenogenesis. Sci. Agric. 21: 245-305.

Steffan, J. R.
1952. Note sur les especes Europeenes et Nord-Africaines du genre Monodontomerus Westw. (Hymenoptera: Torymidae) et leurs hotes. Bull. Mus. Natl. d'Hist. Nat. Ser. 2, 24: 288-293.

Thompson, W. R.
1944. Parasites of the Hymenoptera, Isopoda, and Isoptera, Part IV. Parasite host catalogue section I. A catalogue of the parasites and predators of insect pests. Imp. Agric. Bur., Inst. Entomol., Parasite Serv., Belleville, Ontario, p. 44-45.

Viereck, H. L.
1928. A report on the Hymenoptera of the N.Y. State Museum. N.Y. State Mus. Bull. 274: 177-197.

Walker, F.
1847. Notes on some Chalcidites and Cynipites in the collection of the Rev. F. W. Hope. Ann. & Mag. Nat. Hist. Ser. 1, 19: 227-231.

Watson, W. Y., and Arthur, A. P.
1959. Parasites of the European pine shoot moth, Rhyacionia buoliana (Schiff.), in Ontario. Can. Entomol. 91: 478-484.

Weiss, H. B.
1917a. Additions to the insects of New Jersey, No. 5. Entomol. News 28: 214-221.

Weiss, H. B.
1917b. Notes on several insects not heretofore recorded from New Jersey. J. Econ. Entomol. 10: 224.

Weiss, H. B.
1918. The control of imported pests recently found in New Jersey. J. Econ. Entomol. 11: 122-125.

Westwood, J. O.
1833. Descriptions of several new British forms amongst the parasitic hymenopterous insects. Philos. Mag. Ser. 3, 2: 443-445.

Wilkinson, R. C.
1969. Control of the red-headed pine sawfly. Sunshine State Agric. Res. Rep. Nov., 1969, p. 13-15.

☆U.S. G.P.O.: 1975-640-941/437

Fedde, Vicki H.
1974. Current knowledge of Monodontomerus dentipes (Dalman), a cocoon parasite of pine sawflies. USDA For. Serv. Gen. Tech. Rep. SE-6,19 p. Southeast. For. Exp. Stn., Asheville, N.C.

A literature review on Monodontomerus dentipes (Dalman), including the systematics, morphology, hosts, distribution, and life history of the sawfly cocoon parasite.

The Forest Service, U. S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

MANUAL

SE 7

MODERN GUM NAVAL STORES METHODS

UNIVERSITY
AUG 8 19

by

Ralph W. Clements

aal Stores and Timber
Foduction Laboratory
Olustee, Florida

EARTMENT OF AGRICULTURE
FOREST SERVICE

SOUTHEASTERN FOREST EXPERIMENT STATION
ASHEVILLE, NORTH CAROLINA

D. Forest Service General Technical Report SE-7 December 1974

Drawings by

HARRY ROSSOLL

U.S. Forest Service
Southern Region
Atlanta, Ga.

This manual is a revised edition of one published originally in 1960.

Citation:

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The most efficient gum extraction methods are illustrated by photographs and drawings.

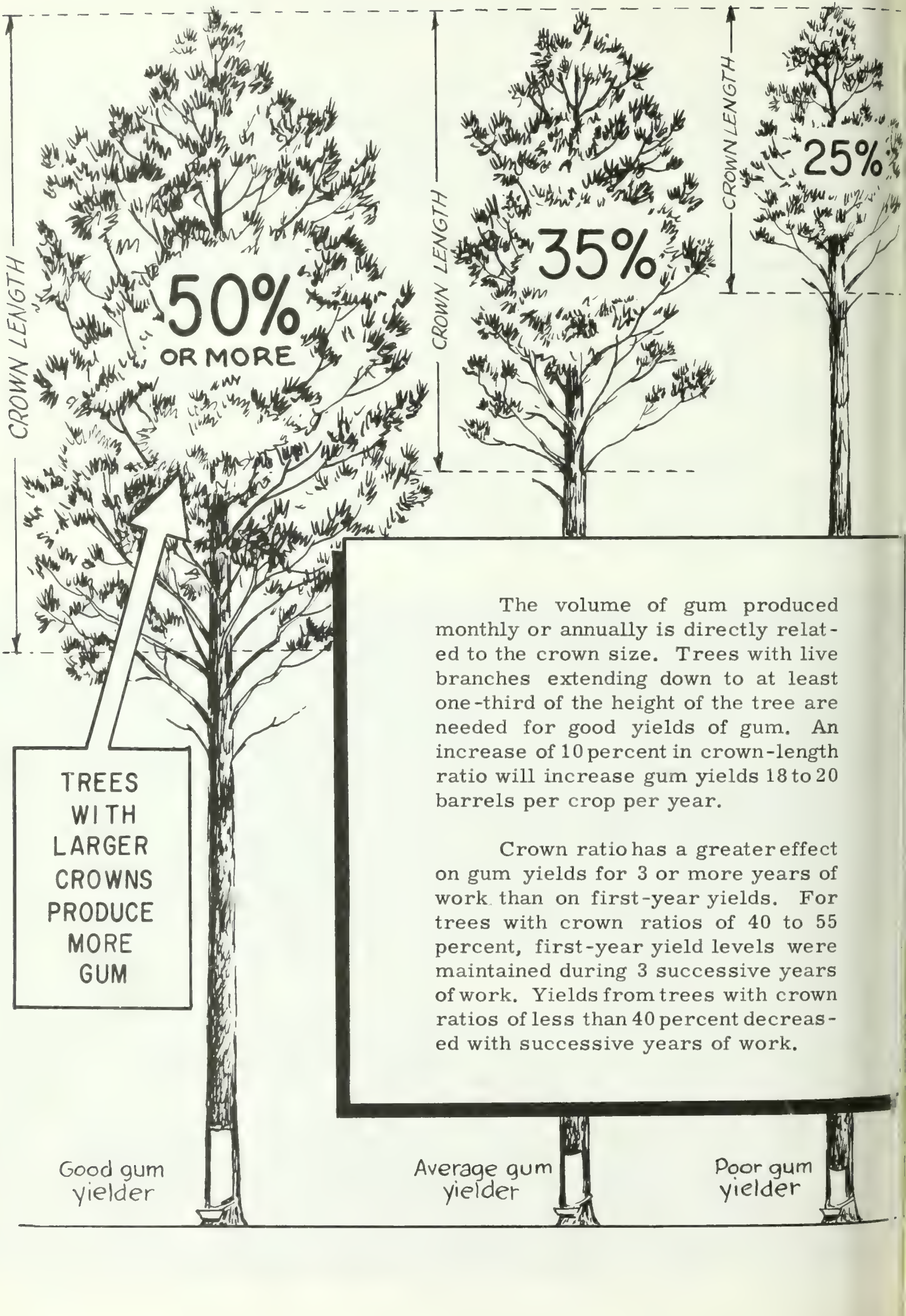
INTRODUCTION

Modern gum naval stores methods have been developed to benefit both the gum producer and the timber owner. Following the methods described in this booklet will bring maximum gum yields, will reduce chipping-labor requirements about 50 percent, and will make the worked-out tree saleable for other wood products.

If these modern turpentining methods are used, naval stores can be integrated in the management plan for pine timbered lands, and timber owners can almost double the dollar value per tree by leasing or working for naval stores before they harvest.

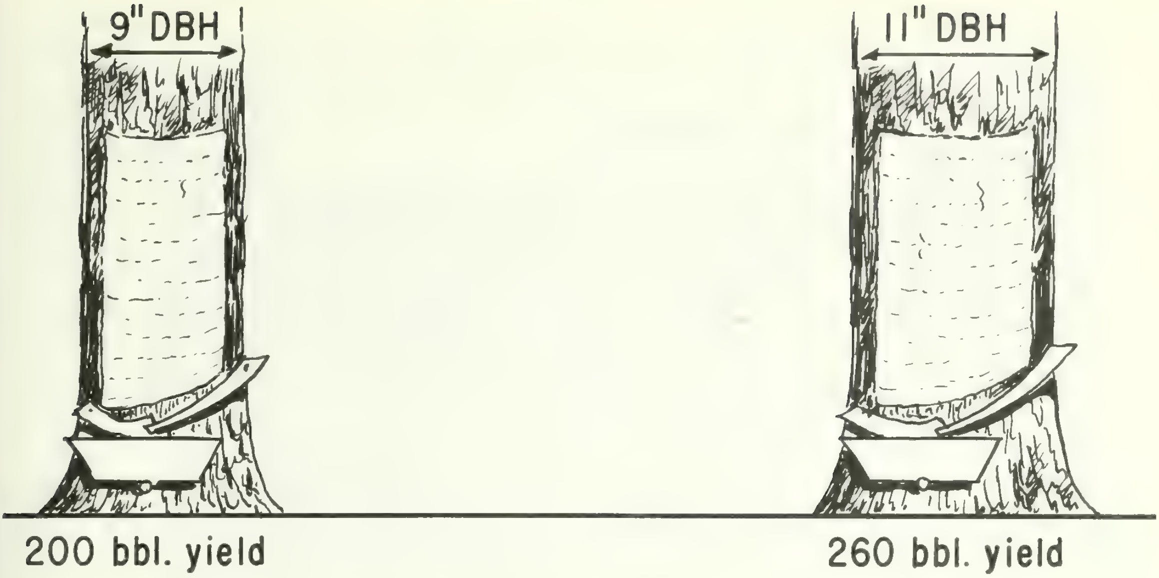
The aim of this booklet is to bring together in one place all the best modern methods of producing gum, and to describe the principal factors that affect gum flow.

The extraction methods and application techniques described here were developed during 15 years of research and testing by scientists at the Lake City Research Center with the cooperation of gum producers and timber owners throughout the gum naval stores belt.



The volume of gum produced monthly or annually is directly related to the crown size. Trees with live branches extending down to at least one-third of the height of the tree are needed for good yields of gum. An increase of 10 percent in crown-length ratio will increase gum yields 18 to 20 barrels per crop per year.

Crown ratio has a greater effect on gum yields for 3 or more years of work than on first-year yields. For trees with crown ratios of 40 to 55 percent, first-year yield levels were maintained during 3 successive years of work. Yields from trees with crown ratios of less than 40 percent decreased with successive years of work.

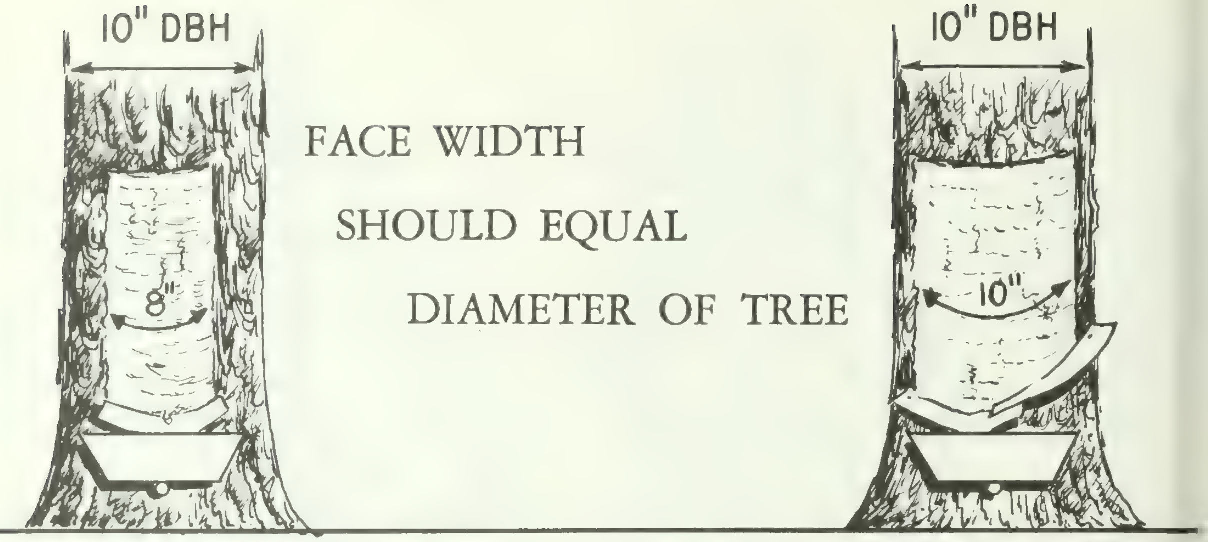


CUP THE LARGER-DIAMETER TREES FOR INCREASED YIELDS AND GREATER PROFITS

A crop of single-faced trees 11 inches in diameter will produce 60 barrels more gum per year than 9-inch trees. The costs for installing tins and for chipping are about the same for 9- and 11-inch trees. The number of small-diameter trees worked can be the difference between break-even and profitable operation.

Double-facing. --Only one face per tree should be installed on trees smaller than 14 inches in diameter. Simultaneous working of two faces installed on one tree does not mean that gum yields from that particular tree will double. The yield from two faces worked simultaneously is normally not more than 70 percent of the yield which could have been obtained from two faces worked one at a time.

Two faces should be installed on trees 14 inches d. b. h. and over for obtaining the greatest yield if the trees are to be worked out in 4 years.



FACE WIDTH SHOULD EQUAL DIAMETER OF TREE

Narrow face width gives poor yield

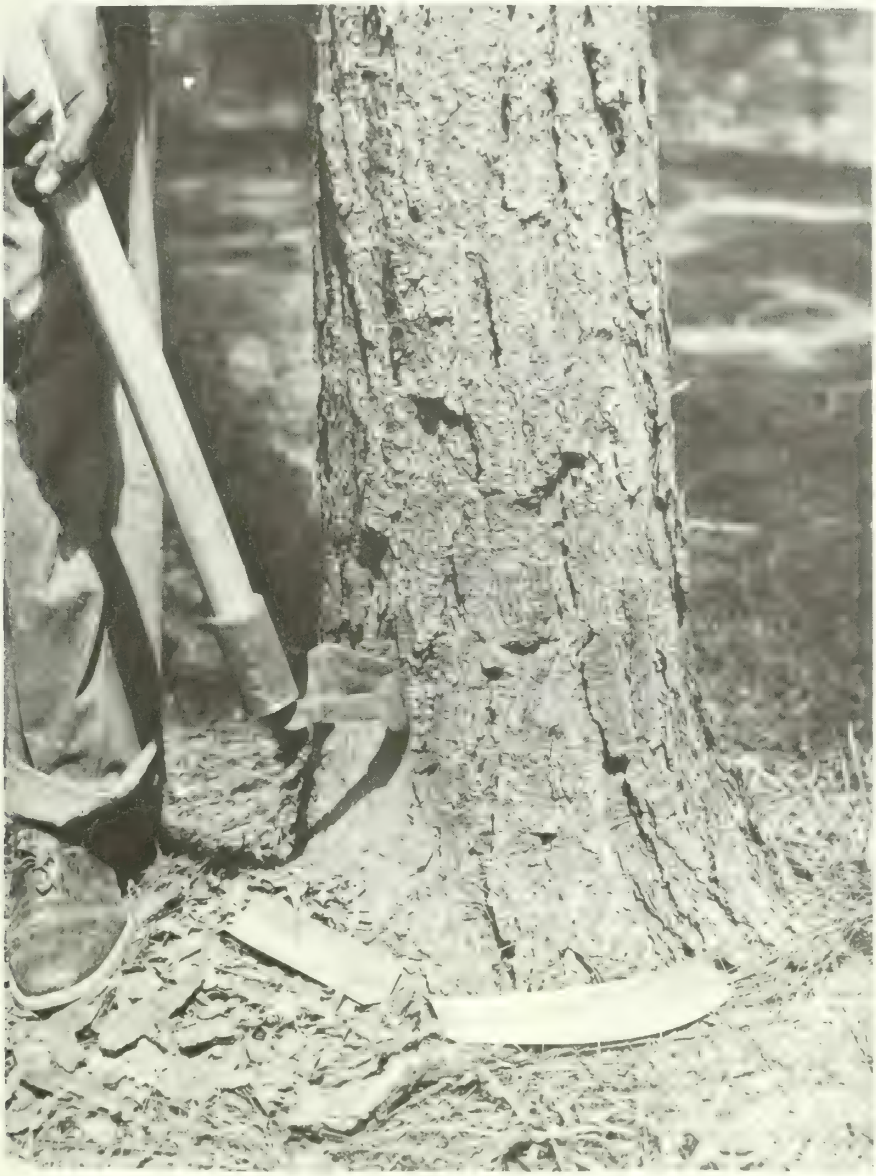
Standard face width gives good yield

The volume of gum produced is directly related to the width of the face. Good gum yields can be obtained with a face width equal to the diameter of the tree measured at breast height. For example, a 10-inch tree should have a 10-inch face and a 12-inch tree a 12-inch face.

Gum yield from shoulders. --With bark chipping and acid treatment, 75 percent of the gum yield at each dipping flows from the shoulders of the face. If careless chipping extends the streak ½ inch beyond the range of the tins on each side of the face, a barrel of gum is wasted during the season for every 310 trees worked.

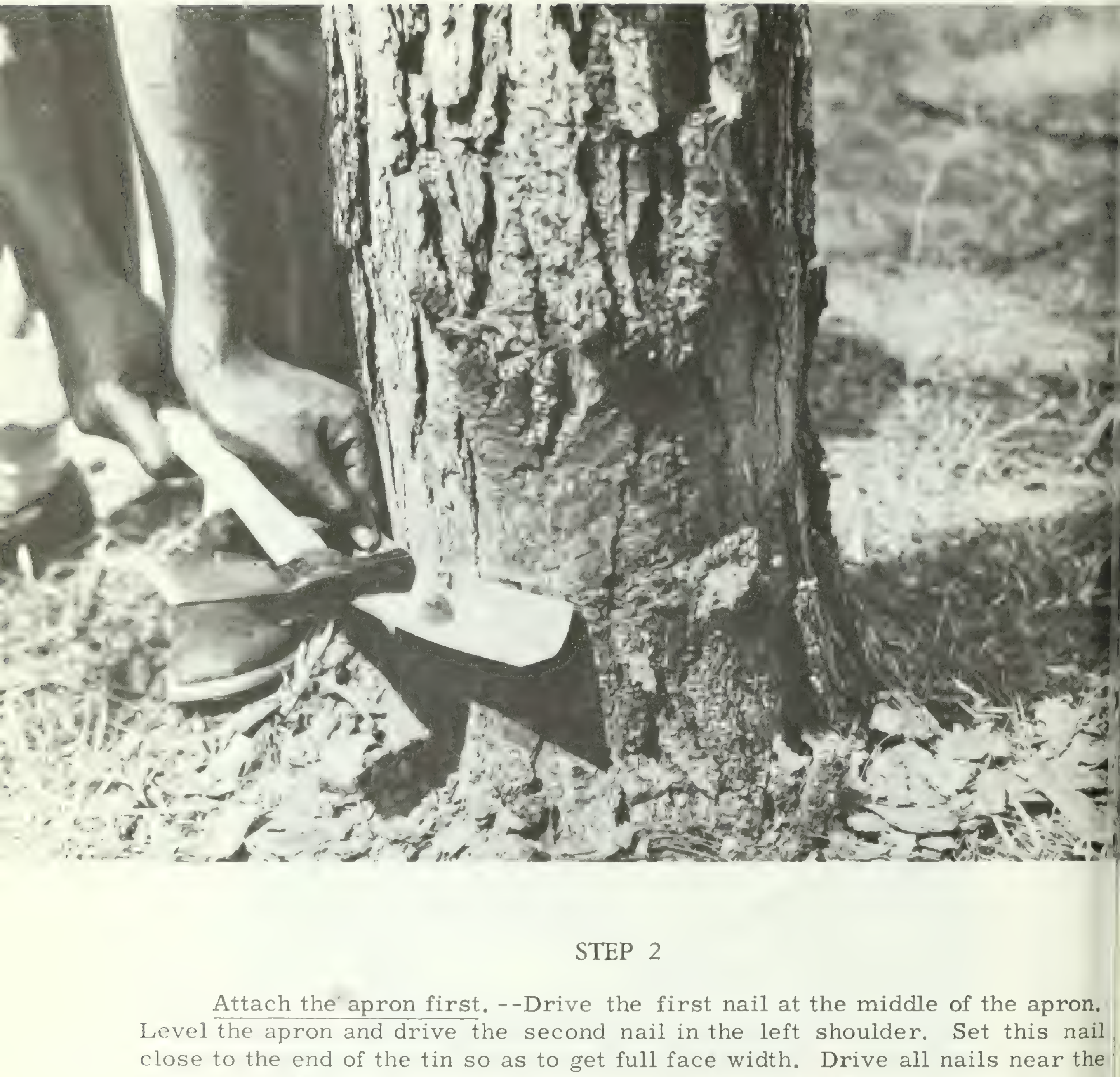
Use correct tin lengths. --One-piece tin assemblies or broadaxe inserted tins will not give full face widths on 12-inch trees and larger. For full face widths and good gum yields, use 10-inch spiral gutters on trees 9 to 12 inches in diameter. Use 12-inch spirals on trees 12 to 16 inches in diameter. For an apron, use a 7- or 8-inch straight or curved gutter with either length.

FIRST-YEAR INSTALLATION OF SPIRAL GUTTERS WITH DOUBLE-HEADED NAILS



STEP 1

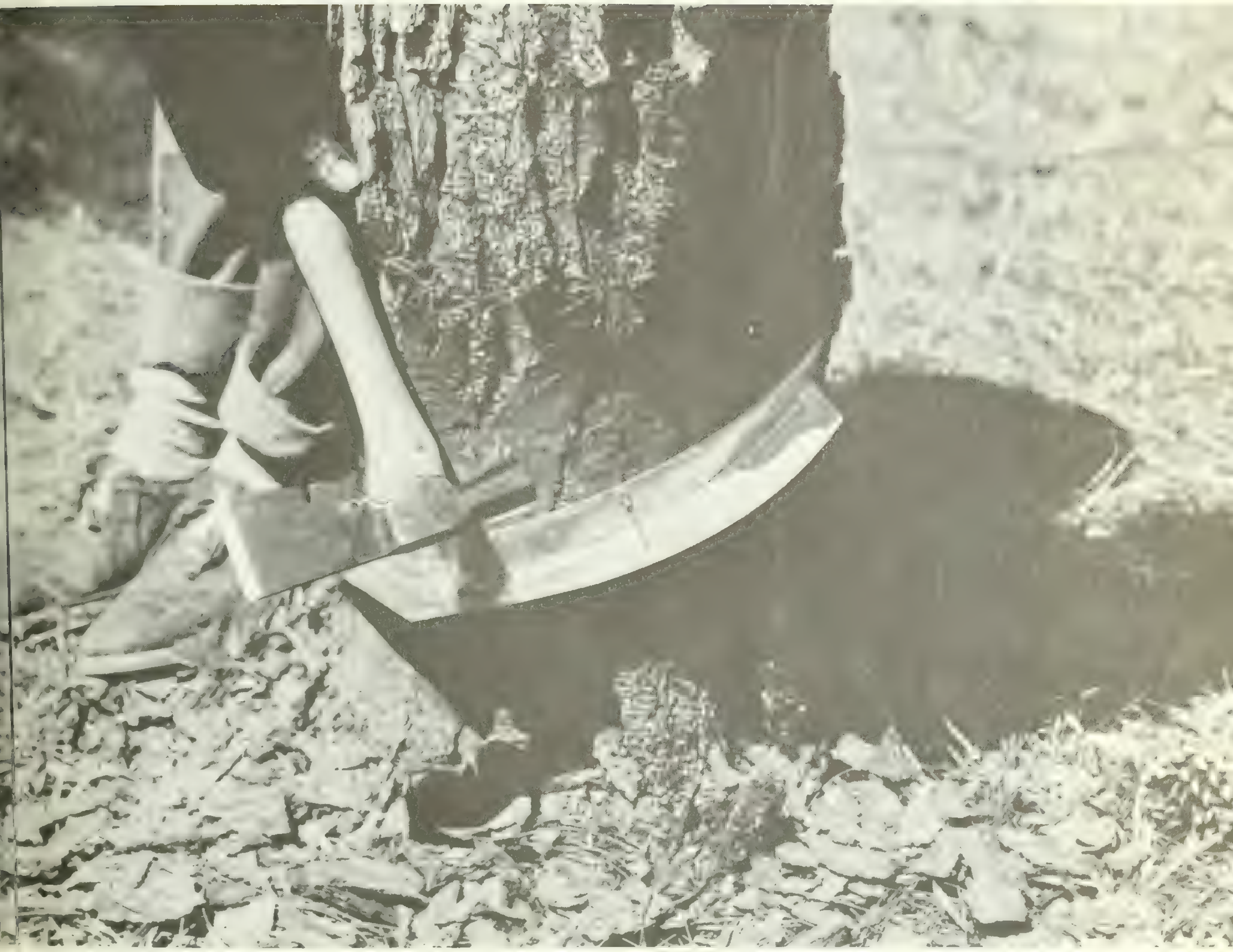
Shaving the bark.--Shave off the rough bark using double-edge, shove-down scrape iron or a bark-shave tool. Shave only the area where the tins will be nailed and the cup will sit. Shave a fairly flat seat for the apron and cup; keep the spiral gutter side of the tree round. Remove enough bark to get rid of the deep cracks.



STEP 2

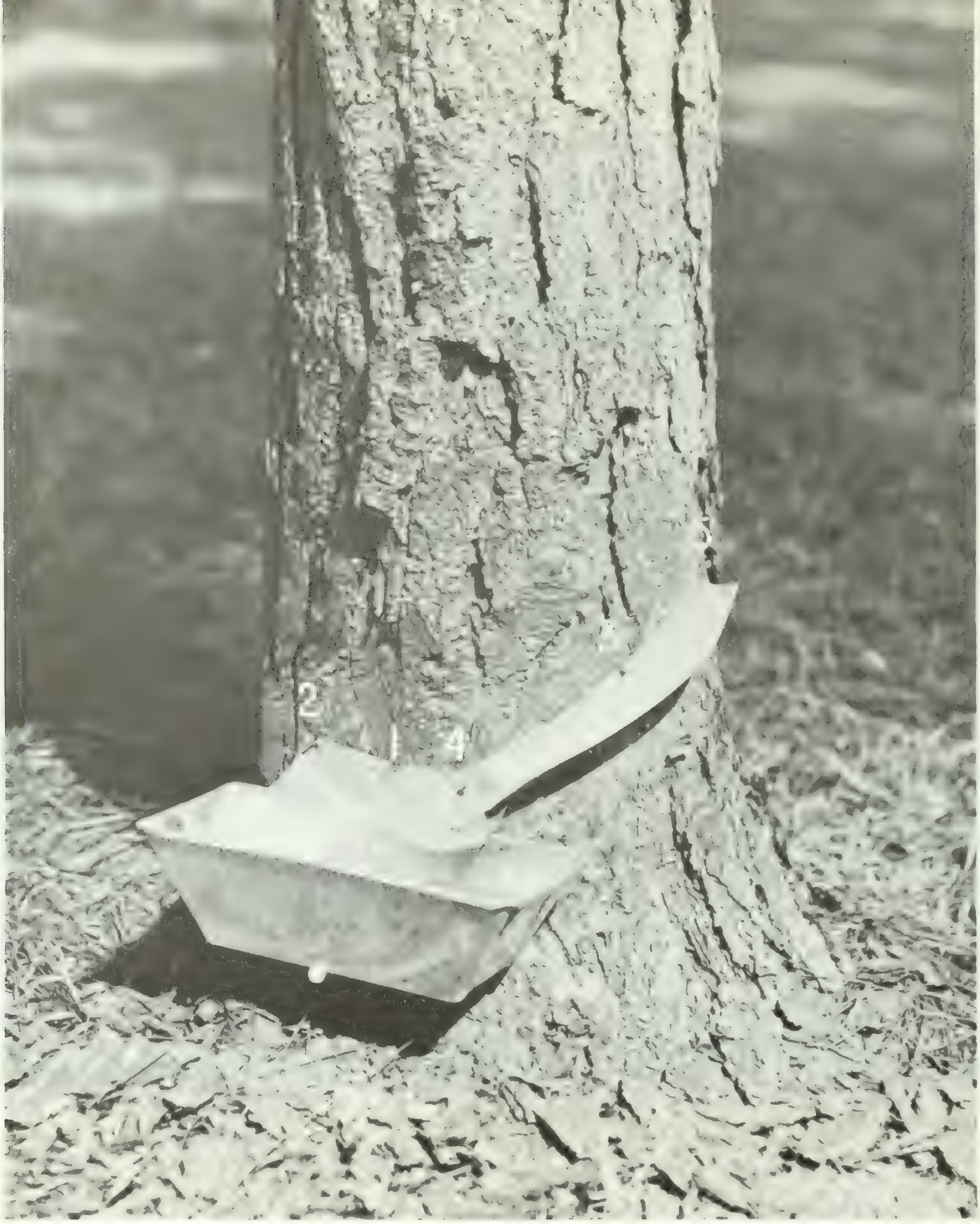
Attach the apron first. --Drive the first nail at the middle of the apron. Level the apron and drive the second nail in the left shoulder. Set this nail close to the end of the tin so as to get full face width. Drive all nails near the top edge of the tins; this pulls the edge into the bark to prevent leakage behind the tins. Pound the inner lip of the right-hand end of the apron so that it fits snugly against the tree. Do not nail the right-hand end at this stage.

Use only double-headed nails designed specially for attaching and removing naval stores tins.



STEP 3

Attaching the spiral gutter.--Lap the lower end of the spiral gutter over the right-hand end of the apron. Set the angle of the spiral between 30 and 40 degrees--around 30 for slash and steeper for longleaf pine. Drive the first nail in the middle of the spiral. Drive the next nail through both the spiral gutter and the apron at the overlap. Drive the shoulder nail last. Close any gaps between the gutter and the bark by pounding the inner edge of the gutter into the bark.



COMPLETED INSTALLATION

The double-headed nails are numbered in the photograph to show the order in which they are driven. To support a large 2-quart cup, a 30d flat-head nail is used. A standard-size cup takes a 20d nail. Drive the cup nail at a slight angle so outer edge of cup will snap over nail head. This holds cup snugly against tree.

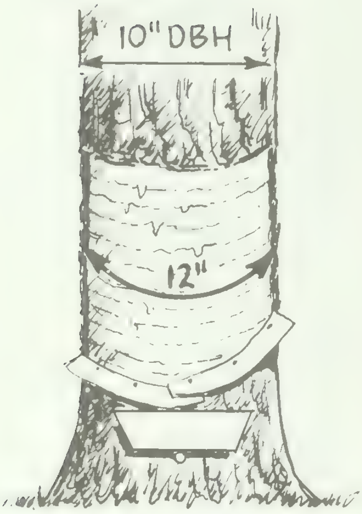
USE OF THE ADVANCED STREAK

With bark chipping and acid treatment, the familiar "lead" or advance streak is not necessary, as it will not increase the volume of gum produced the first year from virgin installations. An advance streak applied 30 days before the regular chipping season begins will give good early-season yields for the first 8 weeks of the season, but yields for the remainder of the season will be reduced proportionally.

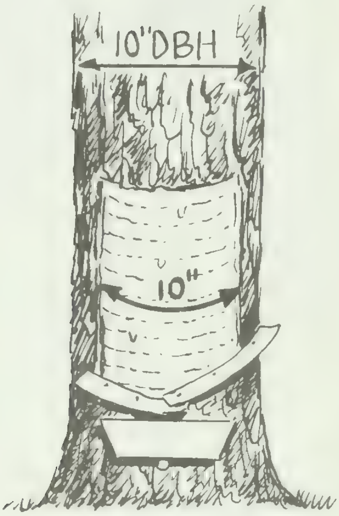
Producers may consider it desirable to produce an increased volume of gum during April and May. There may be a psychological effect in getting something in the cup quickly to spur the interest of chipping and dipping laborers.

The best type of advance streak for good early-season yields is a bark streak $\frac{5}{8}$- to $\frac{3}{4}$-inch high, treated with 50-percent sulfuric acid, applied 30 days in advance of the regular chipping season.

TURPENTINING AND GROWTH



Reduction in growth is related to face width. The wider the face, the slower the growth.

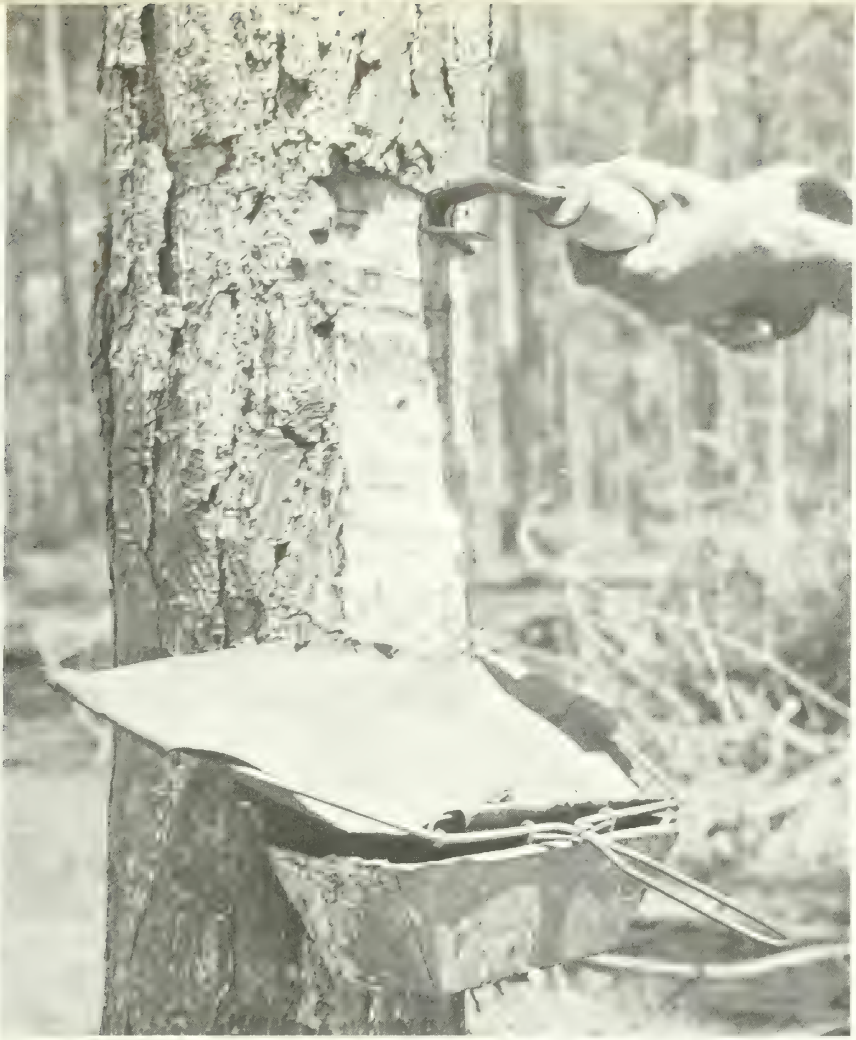


Keep face width equal to diameter of tree to prevent excessive loss in growth.

Measurement data covering a 2-year period from a plantation of 20-year-old slash pine, growing at the rate of 8 annual rings per inch, with 15 x 15 foot spacing, and worked with modern gum extraction methods showed that:

The annual volume increment in cubic feet of turpentined trees was 26 percent less than that of round, unworked trees. This reduction in growth was correlated with the width of the face on the tree; the wider the face on a tree of given size, the slower the growth. For normal face width equal to the diameter of the tree, the annual deficit per turpentined tree would be about 2 cents for pulpwood and 5 cents for saw logs, at current stumpage prices. The gross value for naval stores per year would range from 15 to 25 cents per tree.

Growth loss from turpentining was not directly related to the volume of gum extracted from the tree annually. Thus, the extent of growth loss is the same for indifferent work and poor gum yields, as for skilled work and good yields.



BARK CHIPPING

The bark hack removes the outer, rough bark and the white, inner bark, exposing the gum ducts in the wood. Acid is then sprayed on the surface of the wood. The action of the acid holds these gum ducts open for a period of 2 weeks. It is the acid that makes the gum flow from the tree for the 2-week period. Chipping merely prepares the area for acid treatment. It is not neccessary to cut into the wood with the bark hack, because a wood streak $\frac{1}{2}$ inch deep will not produce any more gum than a streak of bark depth, both treated with acid.

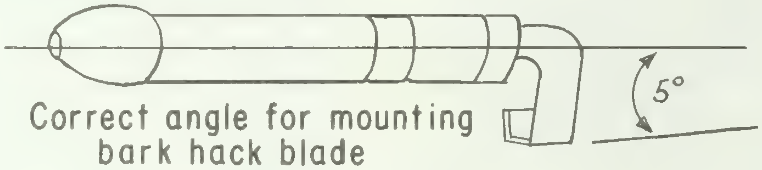
How often to chip and treat.--Treating the streak with acid prolongs the flow of gum; therefore it is necessary to chip and treat only once every 14 days. Chipping and treating every 2 weeks during the chipping season will get practically all of the gum the tree can produce over a period of 4 to 6 years.

Height of streak to chip.--For maximum gum yields over a 4-year period, bark streaks $\frac{3}{4}$ inch high are recommended for both slash and longleaf pine.

MOUNTING AND SHARPENING THE BARK HACK

The bark hack has been designed with a special flat bill, square corners and high jaws to cut through two thicknesses of bark. If it is correctly mounted and sharpened, clean streaks can be chipped and blades will last several years.

The angle (called "pitch") at which the hack head is mounted in the wooden stock helps to prevent chipping into the wood. The best mounting angle for speedy bark chipping is shown below.

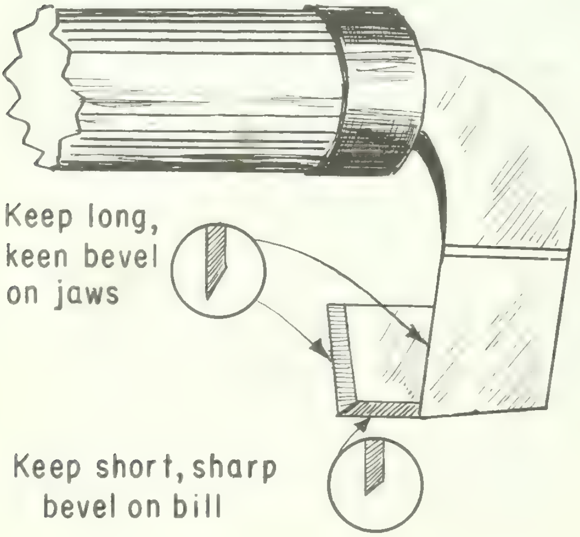


Correct angle for mounting bark hack blade

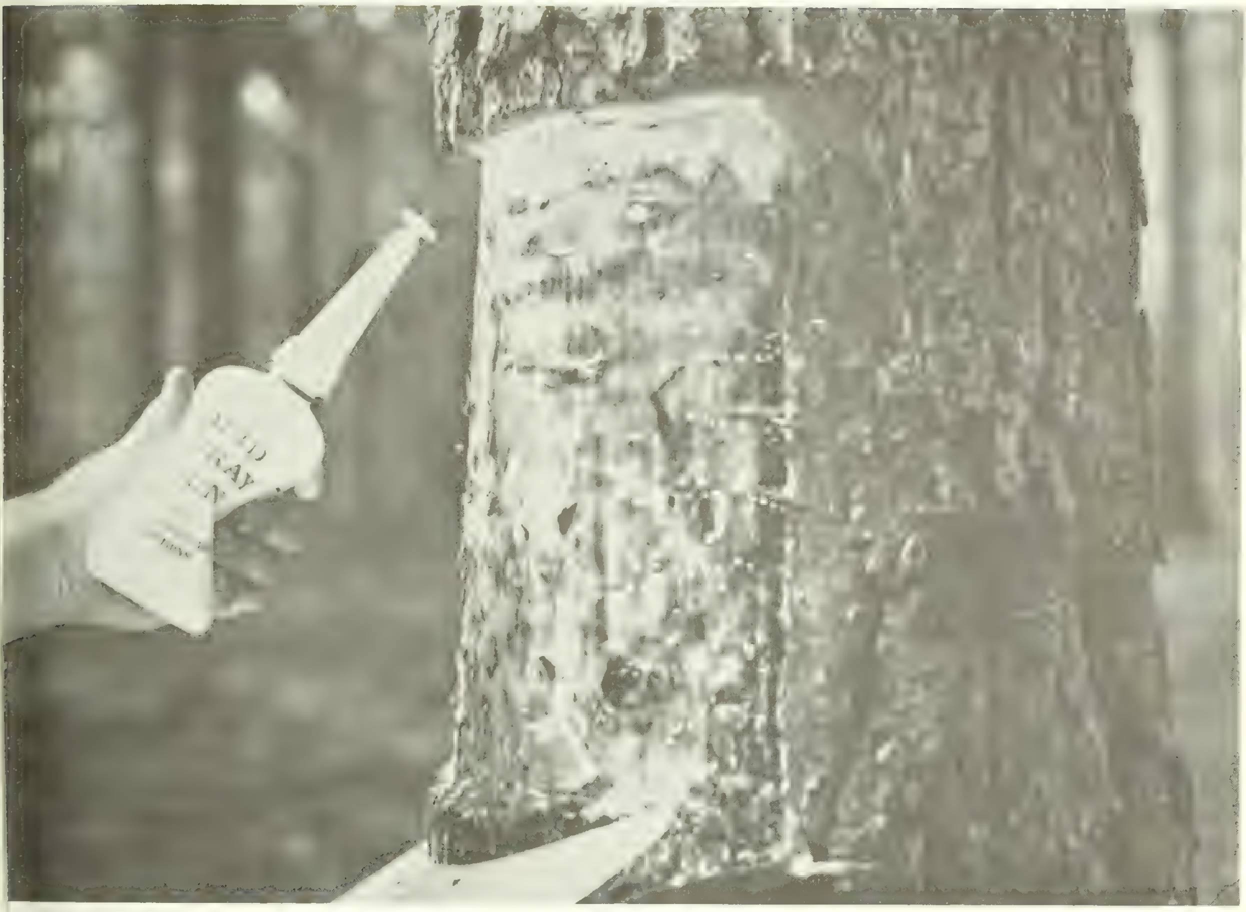
Proper sharpening of a bark hack blade contributes greatly to the chipping of a clean streak and actually determines how long a blade will last.

A steel cutter may be used to cut out and to thin the edges of a new blade, as illustrated below, but the final sharpening touches should be with a flat file. Do not use the cutter to resharpen the edges; use the flat file or whetstone.

Quite often laborers will file a long, keen bevel at the bill to make wood-cutting easier. But the corners will soon break, leaving large gaps in the blade. The blade should be filed so that the corners are kept square at all times. A rounded or gapped corner will leave patches of inner bark in the streak. These patches of bark will stop the flow of gum from above the streak and reduce monthly yields.


Keep long, keen bevel on jaws
Keep short, sharp bevel on bill

In many instances, poor gum yields from bark chipping and acid treatment have been traced directly to such a simple cause as improperly sharpened hack blades. To reduce the excessive breakage of blades, for speedier bark chipping, and for maximum gum flow from each streak, producers should occasionally check with their laborers on the sharpening and mounting of bark hack blades.



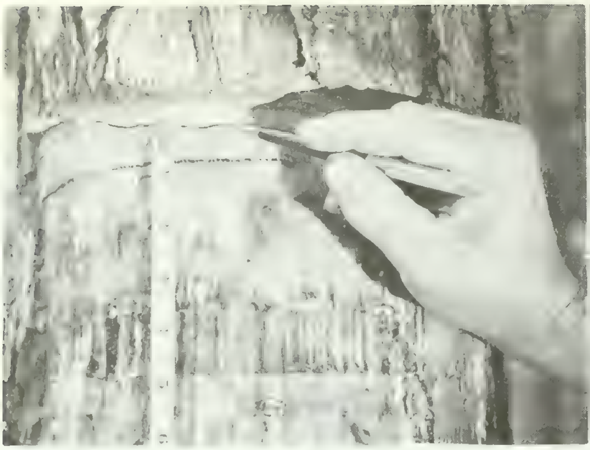
TREATING THE STREAK

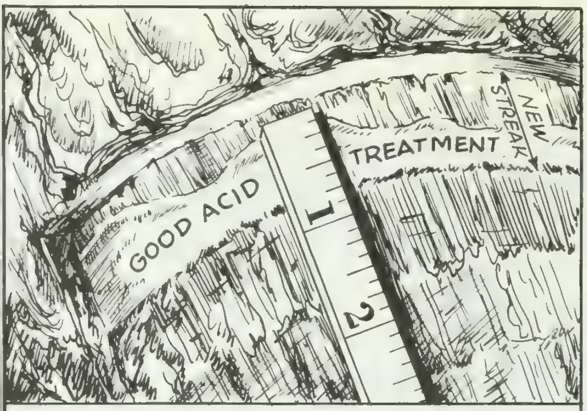
The difference between poor and good yields each month is directly related to the amount of acid properly sprayed on each freshly chipped streak.

A 50-percent solution of sulfuric acid is used on both slash and longleaf pine. The plastic bottle of the acid sprayer is filled only two-thirds full, and the sprayer is held at a 45-degree angle for obtaining good treatment. Keep the nozzle tip from 1 to 2 inches below the top of the streak and from 1 to 2 inches away from the tree. Move the sprayer in one steady motion across the streak, spraying enough acid to wet the streak thoroughly from shoulder to shoulder.

The sprayer should be aimed so that the spray from the nozzle hits the streak at the line where bark meets wood. The acid should be discharged from the sprayer in the form of a spray. Normally, a stream of acid does not give good treatment, because a stream hits the streak with force, spatters and the major portion runs down the face as waste.

Good treatment is of vital importance, and laborers must be consistently supervised to assure quality treatment for profitable gum yields.





Good treatment yields more gum

ACID PENETRATION ABOVE THE STREAK

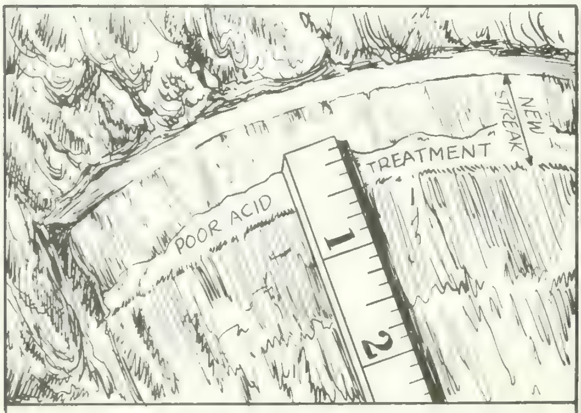
For acid treatment to be effective, the acid must penetrate the area abov the exposed wood at the streak line. Acid penetration causes a reddish-brow color in the white, inner bark and on the surface of the wood. Penetration abov the streak is necessary and is obtained only by good treatment, in which th streak is wet thoroughly and evenly.

Height of acid penetration. --The volume of gum produced by each strea is directly related to the distance the acid penetrates above the streak; th higher the penetration, the greater the yield. The penetration line and th tissues killed by acid treatment can be seen when the next streak is chipped

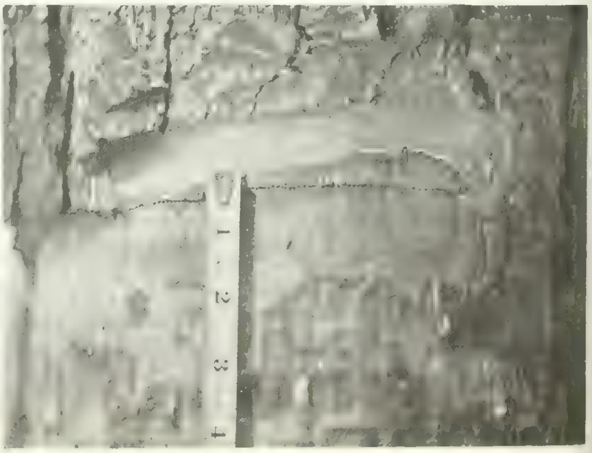
Normally, 50-percent sulfuric acid properly applied in sufficient quantit will penetrate $\frac{1}{2}$ to $\frac{3}{4}$ inch above the streak in 14 days. Good penetration is ob- tained by using the acid sprayer correctly, as the acid must be sprayed into th top portion of the streak. Through careless application, most laborers wast more acid per streak than is needed for good treatment.

If the height of acid penetration is under $\frac{1}{2}$ inch, then treatment has bee poor, and maximum yields will not be obtained from that streak. Poor treatmen can usually be traced to careless application.

For best gum yield, the tissues killed by acid penetration should be re- moved and fresh green wood exposed with each streak chipped. Serious yiel decline may result unless the chipping keeps up with the acid penetration.



Careless application gives poor yield



WOUNDING THE TREE FOR GUM PRODUCTION

A simplification of some of the factors which influence gum flow and annual yield should provide guidelines for the gum producer and his labor to follow for obtaining increased production.

A tree must be "wounded" to induce gum flow, and "flow" can be defined as drainage of gum from the portion of the duct system tapped in the wounding process. Gum is stored in both vertical and radial ducts which traverse the trunk of the pine tree. The number of these ducts wounded or tapped is directly related to the volume of gum produced weekly, monthly, and annually. Therefore, it is obvious that a 12-inch face width will produce more gum than an 8-inch width--more gum ducts are tapped for drainage.

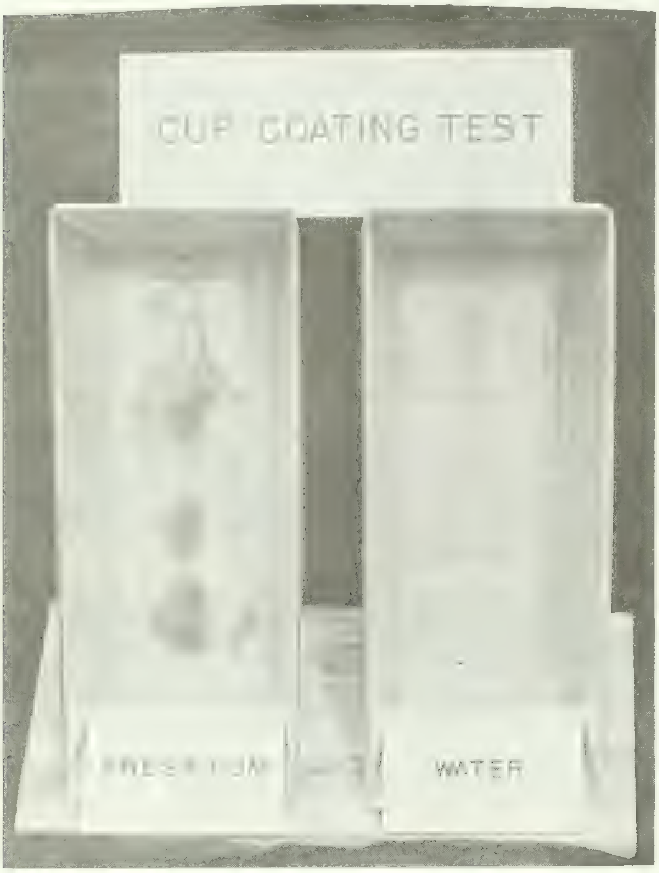
Sulfuric acid is the wounding agent which taps the gum ducts in a vertical direction. The height of the wounding effect (penetration) determines the number of ducts drained for gum yield per streak. One inch of penetration will tap more ducts and produce more gum than $\frac{1}{2}$ inch of penetration.

Acid may be sprayed on in liquid solution or applied as a paste. Virtually one half the volume of solution applied will run down the face as waste. Penetration will peak in about 14 days, then gum flow declines rapidly. The paste holds the acid in position to prevent runoff and penetration will continue for 28 days, then gum yields will fall off abruptly. For any type treatment with sulfuric acid, paste or solution, penetration should never exceed 2 inches in height.

Gum will not flow from the duct system in profitable amounts when the air temperature drops below 65° F. No manner of chipping and treating will make the gum flow. Gum will flow in profitable volume when the temperature is 65° F. or higher for at least 30 percent of the time between streaks. This means that 101 hours of 65° temperature would be needed for a 14-day interval, or an average of 7.2 hours each 24-hour day. Plan your streaks in the early spring and late fall when the weather patterns in your locality are favorable for gum flow.

The number of gum ducts
apped for drainage is directly
elated to the vertical height of
he wounded area.

METAL CUPS, ACID CORROSION, AND GUM GRADES



Water protects a new metal cup better than fresh gum.

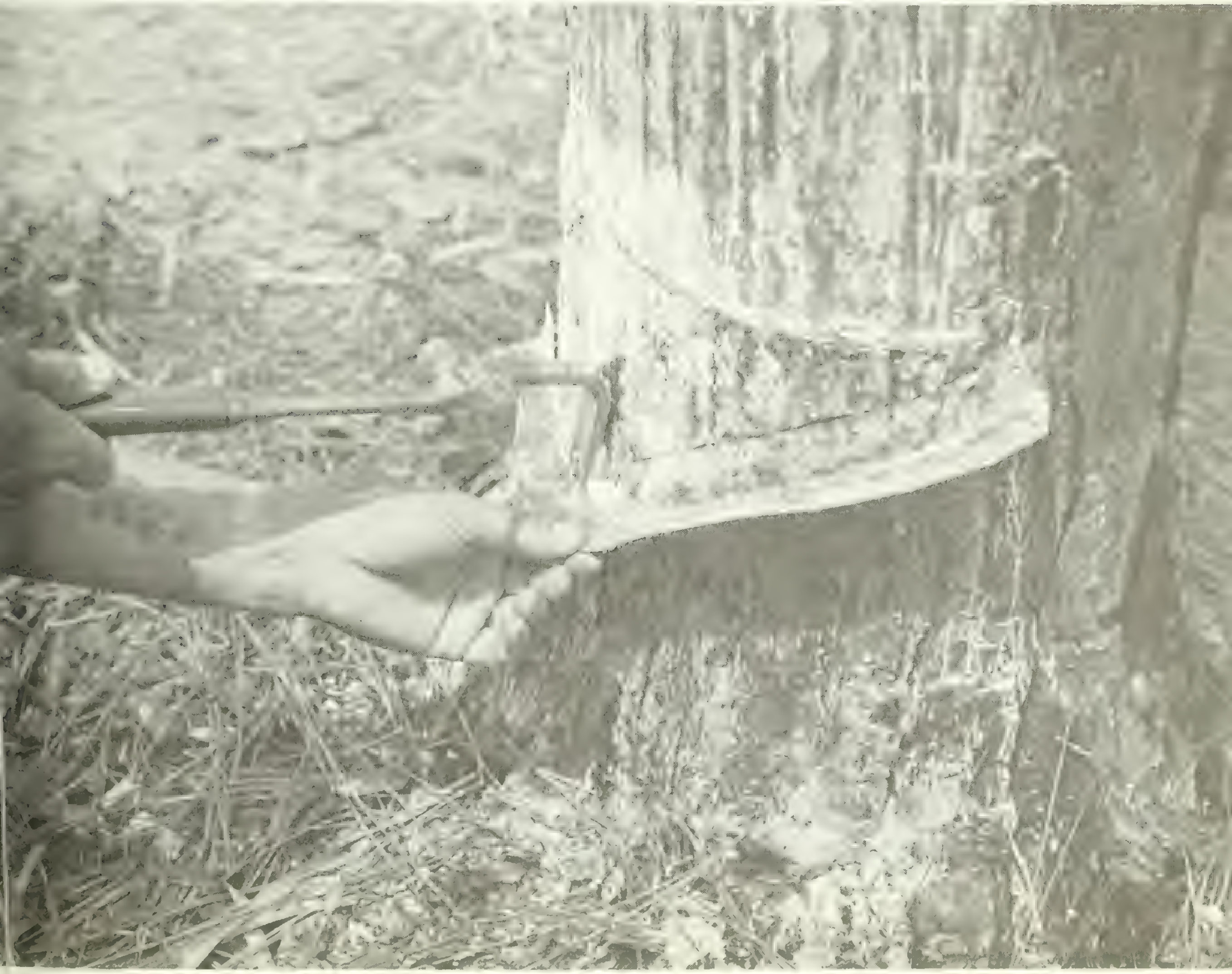
Sulfuric acid will attack the zinc coating and seriously damage galvanized-iron cups. Much of the corrosive damage to new metal cups installed on virgin faces has been traced to waste acid running into the cup from the first 2 to 3 streaks of the season.

Fresh gum will not protect the clean surface of a new cup. Acid infiltrates the gum and eats away the zinc coating, exposing the base metal, iron. Iron contaminants get into the gum, and cloudy rosin results. Only one-tenth of 1 percent iron in the ash content of rosin is needed to lower the grade from WW to D.

Ordinary rainwater in a new cup gives very effective protection. Water dilutes the waste acid and spreads the corrosive action, thereby preventing a concentrated attack in any one spot.

Longer life and good gum grades can be obtained with metal cups if new cups are hung early enough so that normal rainfall will half fill the cups before the first treated streak is applied. Many chippers make a practice of emptying cups that are full of water when the first streak is chipped. Since this water will help protect the zinc coating of the new cups, the practice should be stopped.

RAISING TINS INSTALLED WITH DOUBLE-HEADED NAILS

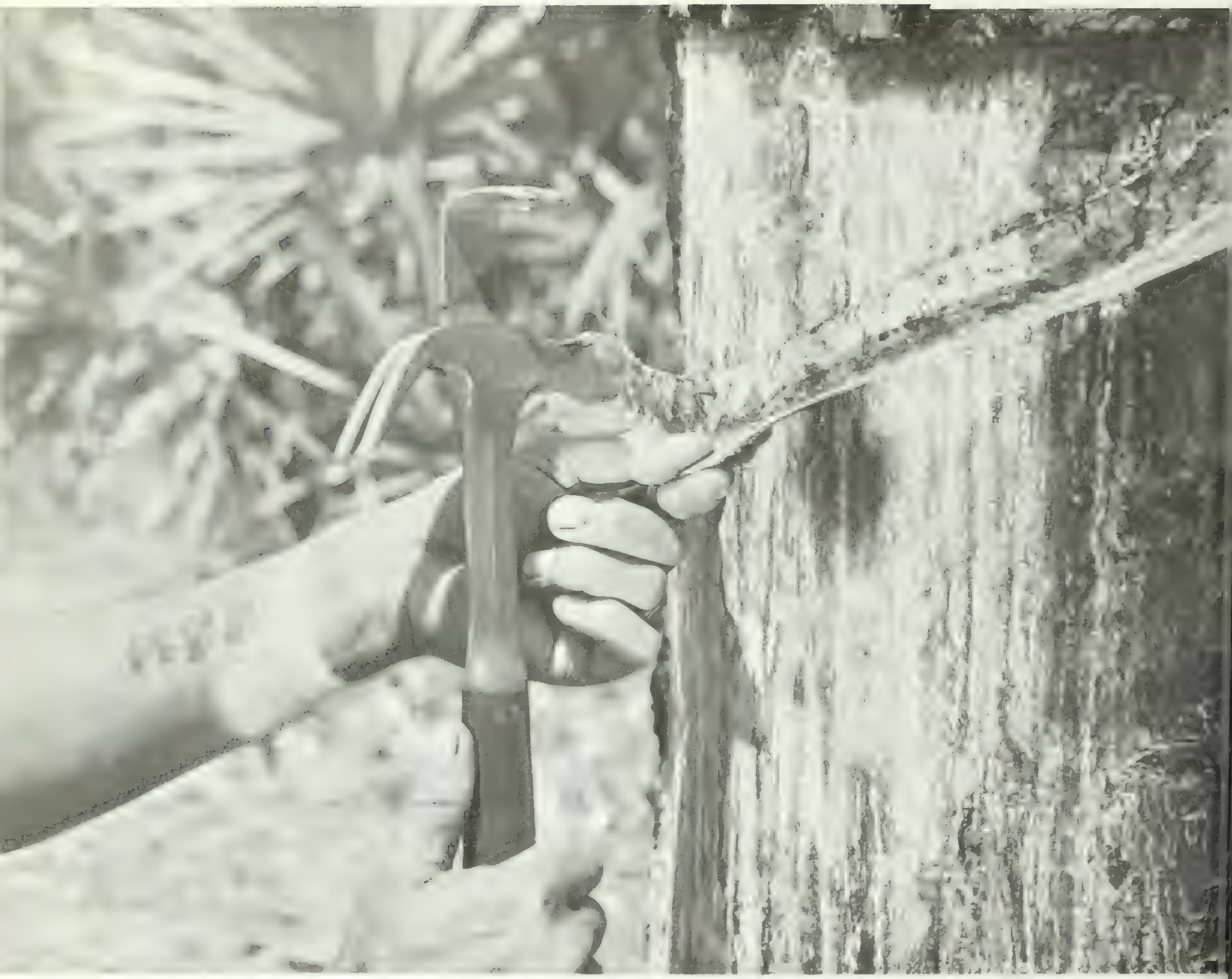


STEP 1

Pulling the double-headed nails.--Pull nails in any order desired except the nail at overlap of gutter and apron, which is pulled last.

Hold the tins at the overlap with the thumb and fingers of the left hand, then pull the lap nail, being careful not to pull the nail completely out of the tins.

Remove the gutter, the apron, and the lap nail from the tree as a unit.

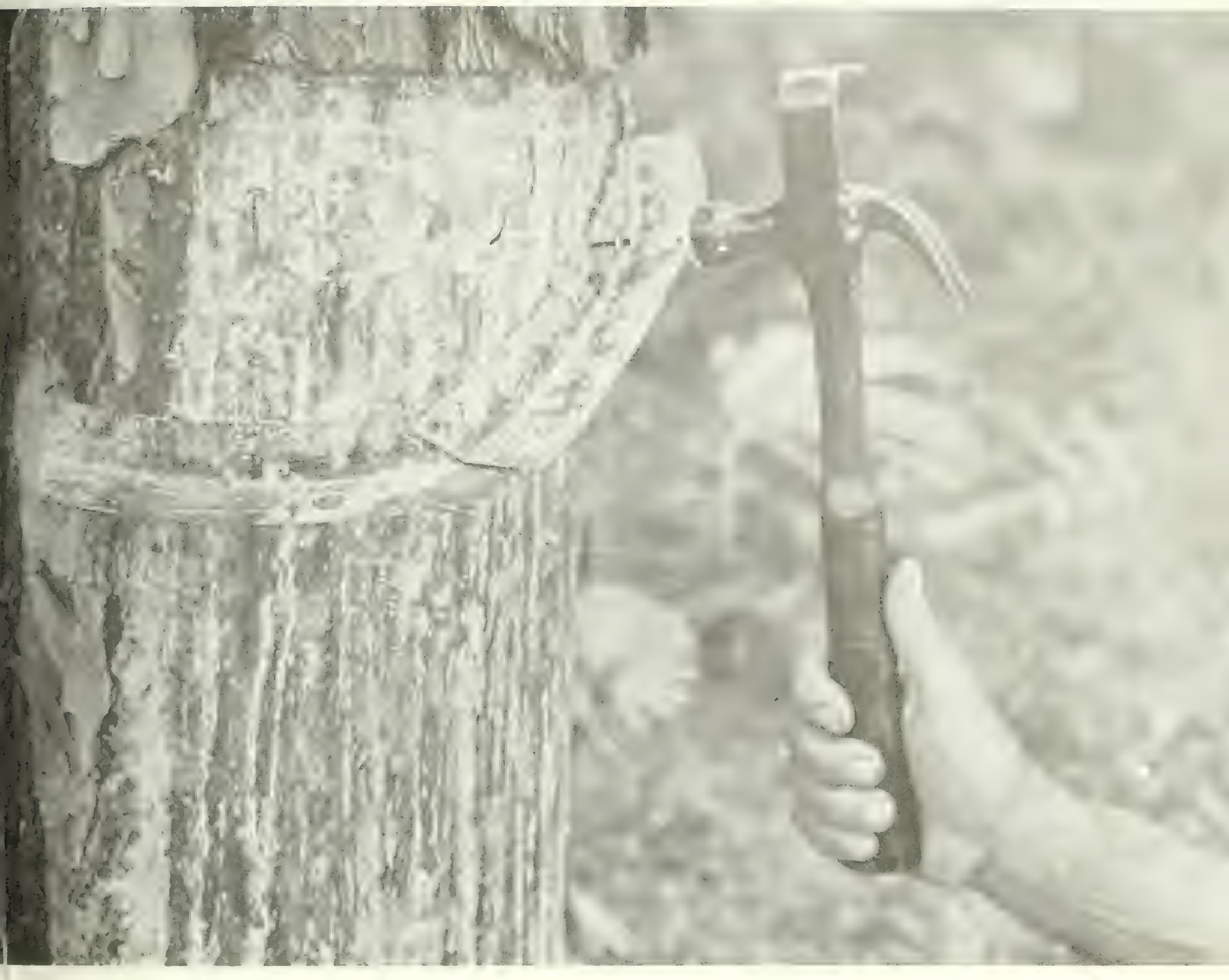


STEP 2

Raising tins to new position. --Raise apron, gutter, and lap nail together as a unit. Position tins accurately on the face of the tree, then drive the lap nail. As this nail is firmly supported in the two tins, it does not have to be held with the fingers while driving it.

The apron on the left and the spiral on the right should extend beyond the shoulders of the face and onto the bark of the tree.

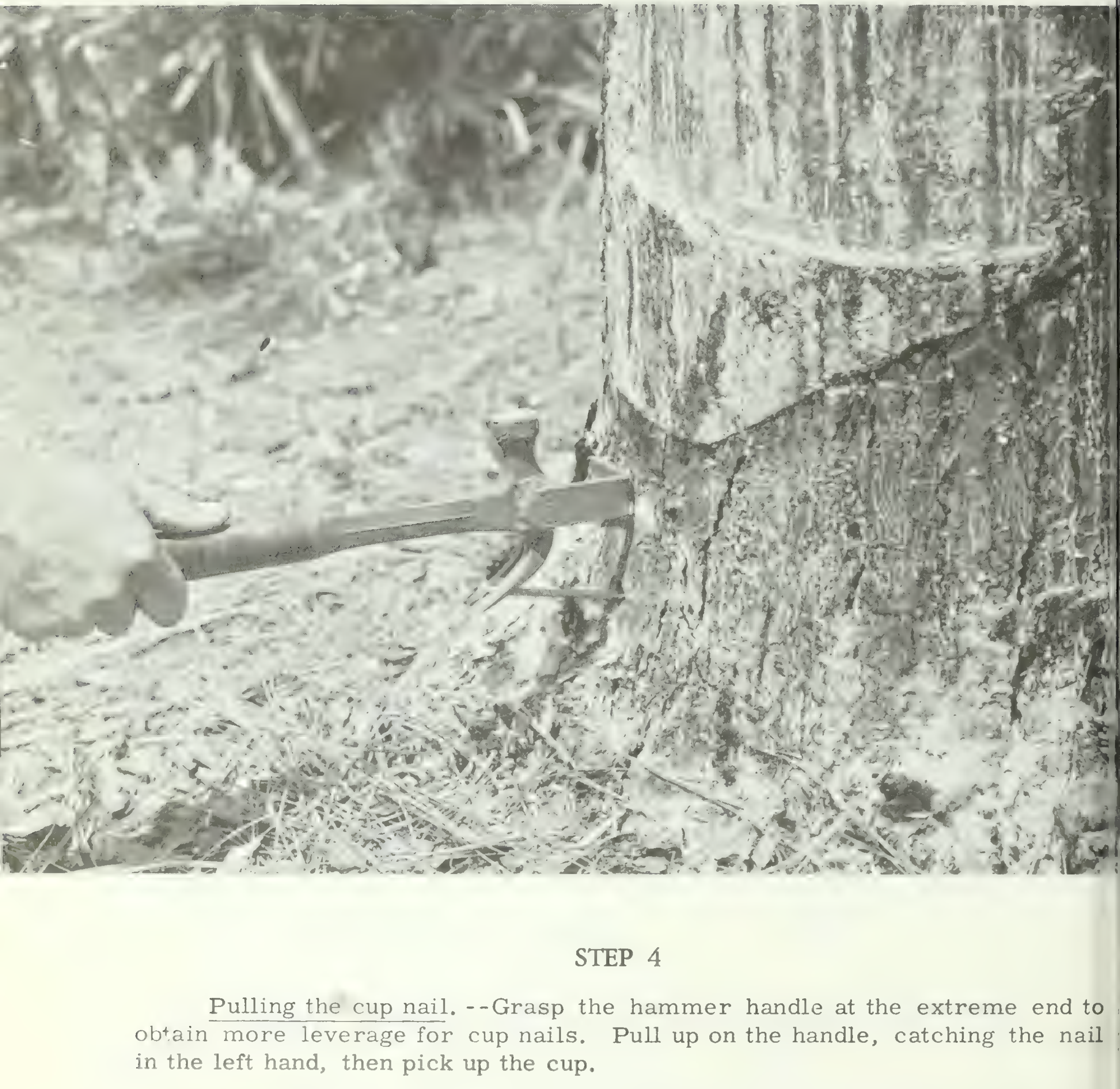
If the spiral gutter does not lap over the apron on the virgin installation, pull all the double-headed nails, then attach the apron first in the raised position. Lap the spiral over the apron and drive the lap nail. As a rule, raised tins will lap much better than on virgin installations.



STEP 3

Driving nails in the tins.--Level the apron and drive the center nail, if used. Then drive the left shoulder nail. Set the spiral gutter at the correct angle for slash or longleaf pine. Drive center nail in the gutter and finally the right shoulder nail. Close any gaps between the tins and face by pounding the inner edge of the tins tight against the face of the tree.

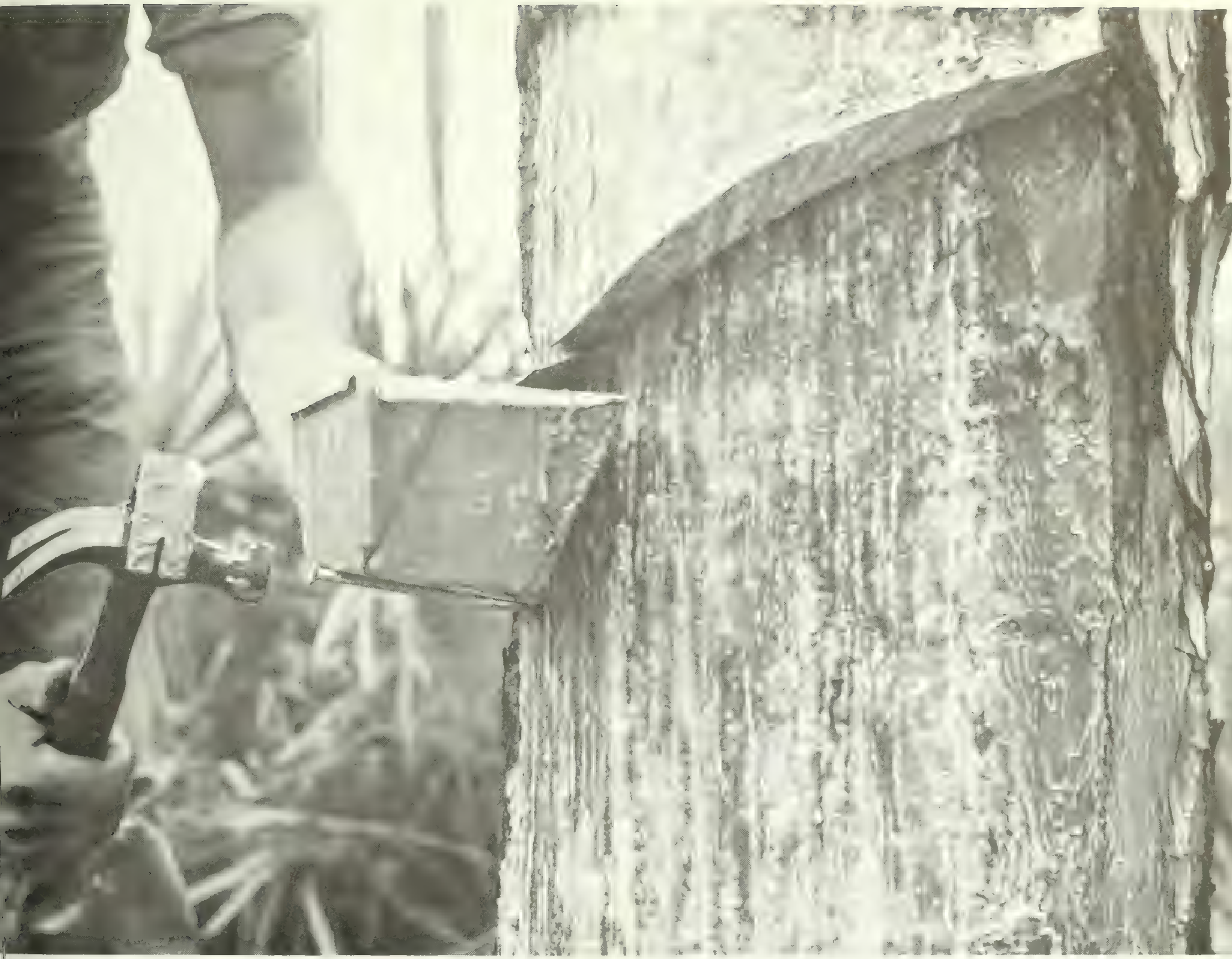
Nails may be redriven in old holes in the tins if the holes are not ripped out or too large. Be careful not to drive the lower head completely through the tin. New nail holes are usually required in tins on both the left and right shoulders of the face.



STEP 4

Pulling the cup nail. --Grasp the hammer handle at the extreme end to obtain more leverage for cup nails. Pull up on the handle, catching the nail in the left hand, then pick up the cup.

For pulling a stubborn cup nail, tap the nail with the driving head of the raising tool. This will break the growth hold of the tree on the nail, making extraction easier.

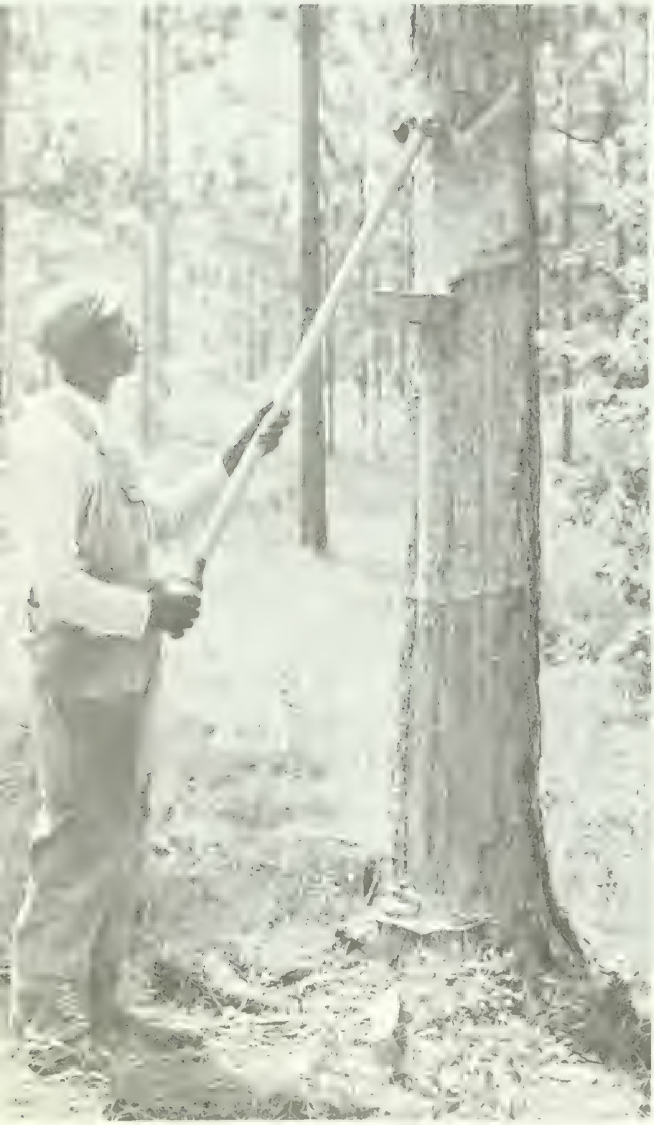


STEP 5

Completing the installation. --Center the cup under the apron and drive the cup nail at a slight angle. Where only one nail is used, the outer bottom edge of the cup should snap inside the nail head. This will hold the cup tight under the apron and against the tree.

Bend the outer lip of the apron downward at the center by tapping with the hammer head. This will help to hold the cup level and prevent tilting, which occurs sometimes on bark-chipped faces.

BARK PULLING AND ACID TREATMENT



Treating a streak on high faces.

Bark pulling enables a producer to continue the bark removal method into the fifth and sixth years, and to preserve the round trunk of the tree for other wood products.

For good monthly yields from slash and longleaf pine, streaks are pulled every 14 days and treated with a 50-percent solution of sulfuric acid. A bark-pulled streak $\frac{3}{4}$ inch in height, with good acid treatment will produce as much gum as two untreated wood-pulled streaks.

It is dangerous to try to treat high pulling streaks with the hand squeeze sprayer, because the laborer has to stand close to the tree, directly under the streak, and the acid spray blows or drifts down on his head or his clothes. He hurries his pass at the streak with the sprayer to get away from the drift, and poor coverage of the streak usually results.

To avoid all this and provide safety and efficiency, the bark-pulling blade and the acid sprayer have been built into one tool, called the SPRAY-PULLER.

The bark-pulling method requires more skill, patience, and time than bark chipping and treating. The key to obtaining good yields with the bark-pulling method is good treatment of the streaks. The under side of the bark and the fresh streak must be thoroughly wet with acid. Always start treatment at the shoulder and move down to the peak; the stock must be held steady, the aim must be accurate, and movement of the nozzle down the streak must be slow

HOW TO USE THE SPRAY-PULLER

Spray-pullers are manufactured in three lengths, 36, 48, and 60 inches. Cost varies with the length. All lengths work satisfactorily on low, fourth-year faces. The 48-inch length is recommended for fifth year and the 60-inch length for high, sixth-year work.

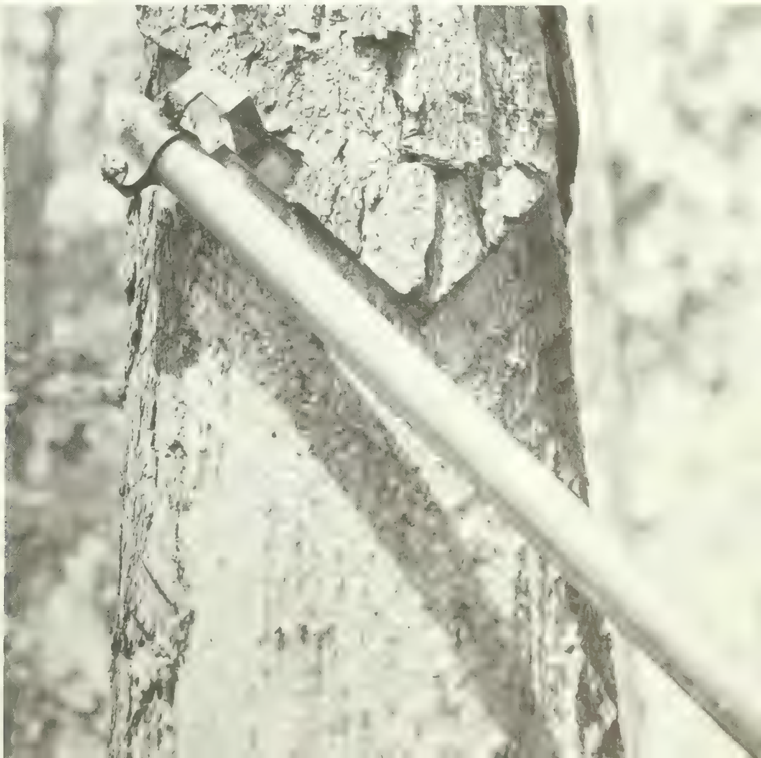
The $\frac{3}{4}$-inch jaw of the puller blade rides against the wood of the tree and determines the height of the streak. In applying the pulling streaks, laborers will find that peaked faces will save time and increase the number of faces they can work each day. Slanted streaks require too much footwork in moving around the tree and are more difficult to treat.

It is impossible by hand-squeeze to force acid the length of the stock from bottle to nozzle. To provide easy discharge of acid by hand-squeeze, an acid trap is located at the upper end of the stock. This trap acts as a reservoir and stores enough acid to treat about 30 trees. When the plastic bottle is squeezed, acid is forced from the trap and out the nozzle.

The trap is filled by inverting the tool and pointing the nozzle at the ground. Continuous acid drip at the nozzle will indicate the trap is filled to its capacity. Usually, refilling is done while the laborer walks from tree to tree.

A supply of acid is carried in the plastic bottle located at the lower end of the aluminum stock. Fill this bottle only two-thirds full of acid, as air space must be left at the top of the bottle.

To assure continued satisfactory performance of the spray-puller, fill the bottle occasionally with clean water and flush the entire sprayer mechanism. Remove the nozzle cap and run clean water through the trap to flush out trash that may have been in the acid.



Correct position for using the puller blade.

ACID PASTE METHOD

SULFURIC ACID PASTE prolongs gum flow for intervals up to 28 days. The paste is safe to use and works equally as well on slash or longleaf pine. The 60-percent acid paste method is ideally suited for the producer who is short of labor. By using longer intervals between streaks, one chipping laborer is able to chip more faces each month, increase gum yields per man-day, and produce a large volume of gum annually from a few streaks. For efficient use of labor, three chipping schedules may be used:

28-day chipping and treating.--Streaks are chipped at regular 28-day intervals, and a total of 8 is applied for the season - March to November. Annual yield should be 85-90 percent of the volume produced by 16 streaks treated with the conventional spray solution. The 28-day interval enables a laborer to chip and treat 75 percent more faces and, as a result, produce 50 percent more gum each month.

21-day interval.--Streaks are chipped and treated every 21 days and a total of 11 applied for the year. Yield should be the same as that produced by the 16-streak, spray-acid method. The chipper should be able to work 32 percent more faces each month.

Stratified chipping schedule.--This schedule utilizes the maximum interval (28 days) between streaks when the nights are cool; the interval is shortened to 21 days and additional streaks applied when the average 24-hour temperature is 70° F. or higher:

Monthly divisions	Interval between streaks	Number of streaks applied
March, April, May	28 days	3
June, July, August	21 days	4
Sept., Oct., Nov.	28 days	3
Total for the year		10

The 10 paste streaks will produce the same volume of gum annually as 16 biweekly streaks treated with the standard spray solution. By using the stratified schedule, an average laborer is able to chip and treat 50 percent more faces per year, produce more gum per man-day, and increase his wages by 59 percent.

APPLYING THE PASTE

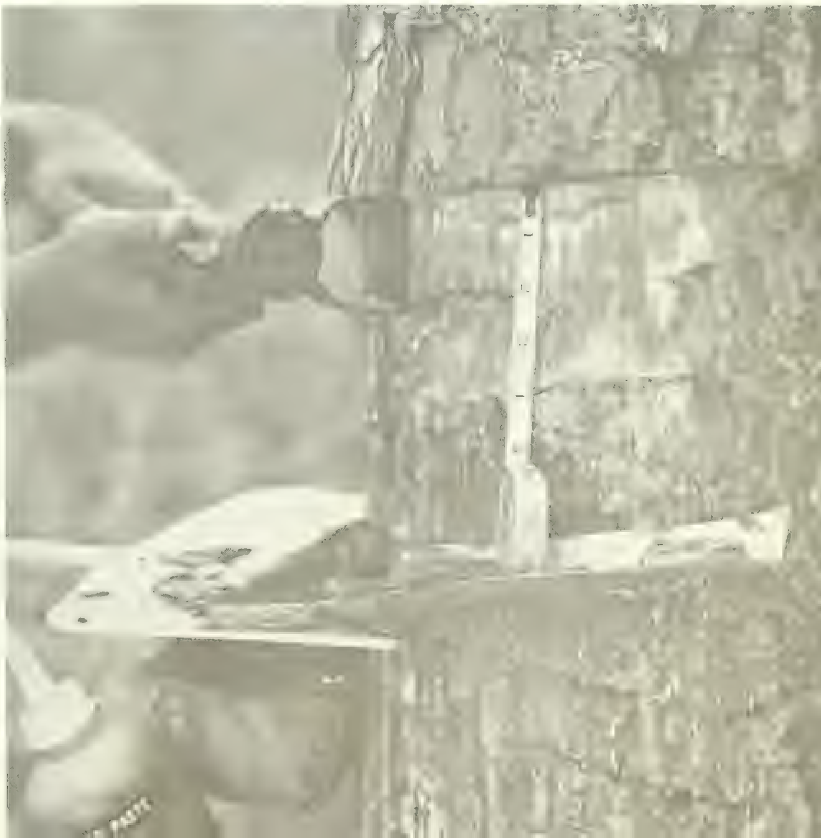
The bead of paste must be placed precisely in the groove formed by the juncture of wood and bark. The tip of the applicator actually "rides" in this groove and touches the tree as the applicator is moved across the streak to "flow" on a bead of paste. A small bead of paste $\frac{1}{8}$ inch in height is sufficient to stimulate gum flow for 28 days.

CHIPPING AND PASTE TREATMENT

The 60-percent sulfuric acid paste continues to penetrate vertically during the third and fourth week to assure gum flow during these extended intervals. As a consequence, tissues are killed higher than with spray-on solutions, and each streak must be chipped higher to reach live tissue. Streak heights for acid paste range from $1\frac{1}{2}$ inches for 21-day chipping to 2 inches for 28-day intervals. The number of streaks applied annually is reduced, so face heights for paste treatments are not appreciably higher than those from 14-day spray-on treatments.

STREAK HEIGHT

Normally, a streak 2 inches in height is required for the 28-day schedule of treatment. If a streak higher than 2 inches is needed, TOO MUCH paste has been applied.



MINIMUM EXPECTED GUM YIELDS FROM SLASH OR LONGLEAF PINE FOR 4 YEARS OF WORK BASED ON FACE WIDTH EQUAL TO D.B.H. OF TREE WITH 35 PERCENT LIVE CROWN LENGTH RATIO

10 paste streaks at stratified intervals

or

16 spray streaks at 14-day intervals

Face width equal to d.b.h. (inches)	Annual yields by year of work[1]			
	1st year	2nd year	3rd year	4th year
	- - - - - - - - - - - - - Barrels per crop - - - - - - - - - - - - -			
8	184	184	175	164
9	199	200	191	182
10	236	239	229	220
11	273	279	267	257
12	310	320	307	298
13	347	358	343	334
14	384	396	380	370
15	421	433	417	405

NOTE: Standard barrel of gum = 435 pounds net.

Crop of faces = 10,000.

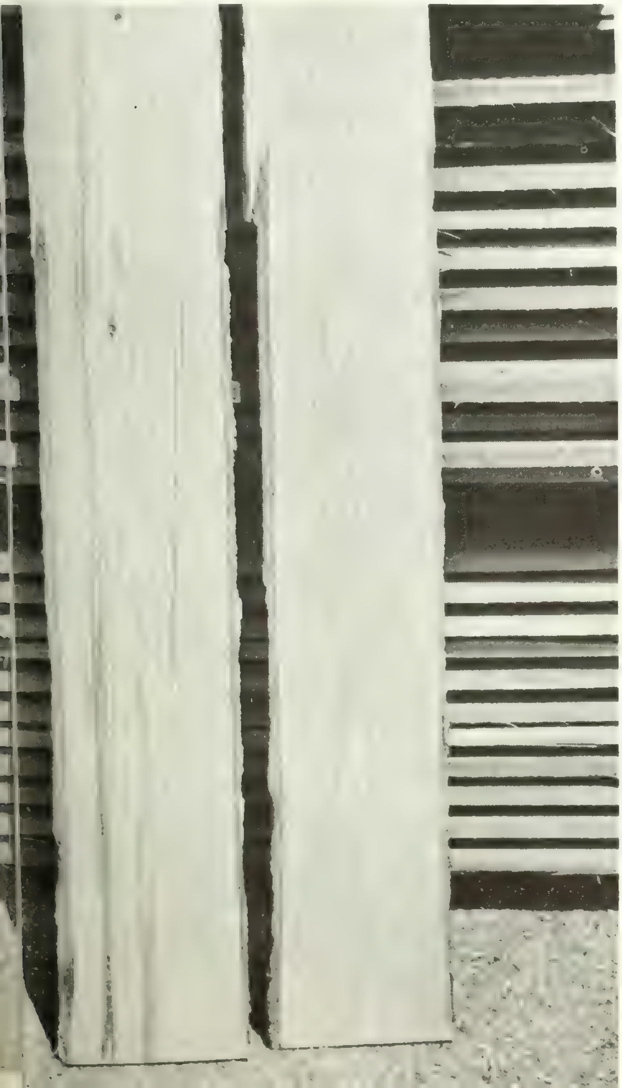
[1] Guidelines for evaluating production. Yields for each diameter class and year of work ma be increased by an excellent quality of workmanship for chipping and treating.

TURPENTINED SECTION SUITABLE FOR OTHER WOOD PRODUCTS

The combined aim of modern gum extraction methods is to get the gum from the tree in profitable quantities and leave the worked-out section suitable for sale for other wood products.

If modern installation and extraction methods are followed, the turpentined section of the tree is suitable for most other wood products. Wood-using industries have shown that unburned, bark-chipped, acid-treated turpentine faces free of all metal and promptly harvested are suitable for saw logs, pulpwood, and many other products at full stumpage value.

No wasteful jump-butts when modern extraction methods are used.



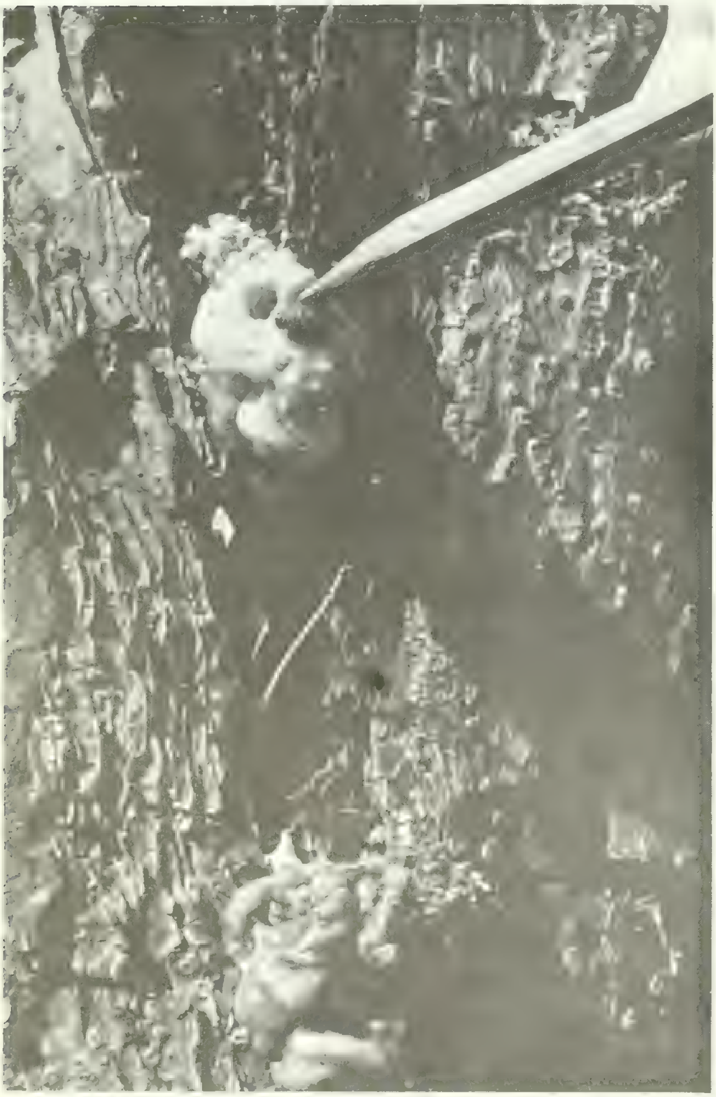
Quality lumber sawn from trees turpentined by modern methods. The untrimmed outside edges of each board show that 2 faces were worked simultaneously for 4 years on each tree.

BEETLE ATTACKS AND CONTROL MEASURES

The black turpentine and Ips beetles have caused considerable damage to pine trees in the South during recent years. Both beetles will attack turpentined and round, unworked trees. However, they can be controlled by alertness for the first attack and by early application of correct control methods.

THE BLACK TURPENTINE BEETLE

This beetle usually attacks the tree within 6 feet of the ground and causes large pitch tubes to appear on the trunk. Beetles are most active during the warm months, and two to three broods may develop during a single year. Excessive and deep chipping, mechanical injury, fire, lightning, and drought make trees more susceptible to beetle attacks. Trees worked-out for naval stores should be cut and marketed.



Pitch tubes made by black turpentine beetles.

Chipping laborers usually spot the first beetle attacks in a drift of timber. These first two or three attacked trees should be promptly sprayed with an acceptable insecticide solution. Do not wait until 15 or 20 trees in the drift show signs of attack before control measures are taken. Early detection and prompt spraying of the attacked trees will help prevent a large-scale infestation at a later date.

To obtain effective penetration of the insecticide solution, it may be necessary to remove some of the excessive, rough bark near the base of the tree. The portion of the tree trunk where the beetles are working should be thoroughly sprayed with a 1% insecticide solution. On faces regularly chipped for gum production, it is advisable to omit the next two streaks. This gives the tree a chance to recover from the beetle attacks and from any adverse effects of the insecticide.

THE IPS BEETLE

The Ips beetle may attack the entire length of the tree or only the top portion. Therefore, it is not always practical to spray standing trees. Early detection is not easy, as the beetles may cause only small pitch tubes or none at all. The best control measure is to keep pine stands in a vigorous condition through a good management program. Infested trees should be cut and removed from the woods; stumps and tops should then be sprayed with a beetle control solution.

SOLUTIONS FOR BEETLE CONTROL

Purchase a commercial concentrate specially prepared for bark beetle control. Two concentrates which are acceptable and have proven to be effective as control sprays are:

Lindane Liquid - 20; 1.6 pounds lindane per gallon of concentrate is used for preparing water solutions.

Benzene Hexachloride (BHC); 1 pound of gamma isomer per gallon (oil solution) is used for preparing oil solutions.

An approximate 1% solution may be prepared as follows:

1 gallon of Lindane concentrate in 20 gallons of water
1 gallon of BHC (oil solution) in 14 gallons No. 2 fuel oil

The water solutions do not penetrate the bark as quickly as oil and do not remain toxic for long periods; therefore, the bark on the tree should be thoroughly drenched with the water solution to assure effective control.

Kerosene or other light oils should never be substituted for No. 2 fuel oil where living trees are to be sprayed, as the substitute oils may kill the trees.

Do not make frequent applications of the oil solutions to the same standing tree. One good application should provide protection for about 6 months.

Immediate action in fighting the black turpentine and Ips beetles is very important. DO NOT WAIT UNTIL YOU HAVE A LARGE-SCALE INFESTATION BEFORE STARTING CONTROL MEASURES. Effective control should begin with the first tree attacked.

BE ALERT FOR BEETLE ATTACKS,
then quick to start control measures!

PROTECT

CAUTION: Insecticides used improperly can be injurious to man, animals, and plants. In preparing solutions and using them in the woods, follow the directions and heed all precautions shown on the labels of the concentrates.

Some states have restrictions on the use of certain insecticides. Check your State and local regulations. Also, because registrations of insecticides are under constant review by the Environmental Protection Agency, consult your County Forester or State Extension specialist to be sure the intended use is still registered.

The key to more efficient gum production

GOOD ACID TREATMENT ON EVERY STREAK

seed and cone insects of southern pines

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General Technical Report/SE-8
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Southeastern Forest Experiment Station
Asheville, North Carolina
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INSECT OCCURRENCE ON HOST PINES

Flower and Conelet Damaging Insects – p. 4

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Table-Mount
Nantucket pine tip moth	No	Yes	Yes	No	Yes	No	N
Slash pine flower thrips	No	No	No	Yes	No	No	N
Pine conelet looper	No	Yes	Yes	Yes	?	No	N
Virginia pine sawfly	No	Yes	Yes	No	Yes	No	N
May beetles	?	?	Yes	?	?	?	?
Pine catkin sawflies	Yes	Yes	Yes	Yes	Yes	Yes	?
Leaffooted pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	Ye
Cone feeding midges	Yes	Yes	Yes	Yes	Yes	?	?
South coastal coneworm	Yes	No	Yes	Yes	No	No	N
Loblolly pine coneworm	Yes	Yes	Yes	Yes	Yes	No	?
Southern pine coneworm	Yes	Yes	Yes	Yes	Yes	No	N
Blister coneworm	Yes	Yes	Yes	Yes	?	No	?

Cone Damaging Insects – p. 12

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Table Moun
Southern pine coneworm	Yes	Yes	Yes	Yes	Yes	No	N
South coastal coneworm	Yes	No	Yes	Yes	No	No	N
Webbing coneworm	No	Yes	Yes	No	Yes	?	[illegible]
Blister coneworm	Yes	Yes	Yes	Yes	?	No	[illegible]
Mountain pine coneworm	No	?	Yes	No	?	No	Y
Loblolly pine coneworm	Yes	Yes	Yes	Yes	Yes	No	[illegible]
Shortleaf pine coneborer	No	Yes	Yes	No	?	No	[illegible]
White pine coneborer	No	No	No	No	Yes	Yes	N
White pine cone beetle	No	No	No	No	?	Yes	N
Cone feeding midges	Yes	Yes	Yes	Yes	Yes	?	[illegible]

Seed Damaging Insects – p. 29

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Tabl Mou
Longleaf pine seedworm	Yes	No	Yes	Yes	No	No	[illegible]
Slash pine seedworm	Uncommon	No	Uncommon	Yes	No	No	[illegible]
Eastern pine seedworm	No	Yes	Yes	No	Yes	No	[illegible]
Leaffooted pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	Y
Shieldback pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	?
Seed chalcid	No	No	No	No	No	Yes	[illegible]

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NSECT ATTACK PERIODS . . . . Inside Back Cover

SOUTHERN PINE SEED AND CONE INSECTS

by

Bernard H. Ebel,[1] *Thomas H. Flavell,*[2] *Loyd E. Drake,*[3]
Harry O. Yates III,[1] *and Gary L. DeBarr*[1]

This booklet is a guide to insects that limit seed production by the major pine species native the Southern United States. It is intended for use primarily by foresters and tree improvem workers. Major emphasis in this guide is on insects of longleaf, shortleaf, loblolly, and slash pi Available information is also provided on other species, including eastern white, Virginia, a Table-Mountain pine. Pitch, pond, spruce, and sand pines are excluded for lack of pertinent data.

Research in recent years has demonstrated that insects are a major factor limiting the product of both cone crops and viable seeds. Before the orchard manager can consider control, however, must know what insects are causing the damage. This guide is designed for such identification, w emphasis on the use of damage specimens.

To most effectively use this guide, samples of the insect damage should be collected, th identified by direct comparison with illustrations provided and by keying of damaged material.

Where it is feasible, the user may wish to collect or rear insects from the damaged host mater This procedure may be needed to positively identify the species of insect pest. To this e photographs, descriptions, and keys to various insect forms are included. Illustrations a descriptions of adults are also useful in the identification of specimens captured in light traps or other means.

The guide groups damage into three categories — flower and conelet damage, cone damage, a seed damage.[4] Each category makes up a separate section of this booklet, and each section beg with a damage identification key. In most instances, the user should begin to identify his ins problem by referring to one of these three keys on the pages indicated:

Flower and Conelet Damage — page 5
Cone Damage — page 13
Seed Damage — page 30

These keys lead to a concise summary of the biology, damage, and importance of each ins species. These summaries represent the concensus of the authors on information gleaned both fr the literature and personal knowledge. Hence, no attempt is made to cite the authority of e statement. However, references are listed by number in parentheses following each species na These numbers refer to the selected references at the end of the guide.

---

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[3] Entomologist, Southeastern Area, State and Private Forestry, Alexandria, La.

[4] These reproductive structures are defined in the glossary on page 38.

Distribution maps are included for all insects species, providing at a glance each insect's expected thern distribution. Knowledge of some distributions is incomplete. Accordingly, the range maps uld be used as general rather than absolute guides.

nsect species and their pine hosts are tabulated for each of the three damage categories (inside nt cover). Insect-host relationships are based upon our present knowledge. In some instances, ect-host associations are uncertain; these are designated by a question mark.

A summary of insect attack periods (inside back cover) shows when each insect species is likely cause damage. It is a further aid in specific identification.

llustrations and a key to the larvae of coneboring caterpillars are included because of the portance of this group, the similarity of the damage they inflict on the host, and the likelihood of larvae being present in the damaged host material collected. A glossary at the end of this guide fines certain technical terms which might be unfamiliar to the user, and a host list provides entific names of the host species.

n identifying the insect causing damage, the reader should make use of as much information as ssible. He should use the range maps, the summary of insect occurrence by host pines, the nmary of insect attack periods, keys, and color photographs. In most instances, the attacking ect may be narrowed down to one or two species using only the colored photographs. Individual scriptions of the insects and their damage should confirm identification in nearly all cases.

FLOWER AND CONELET DAMAGE

This category includes insects that feed primarily on the male and female flowers and develop conelets of pines. Insects that feed on flowers or conelets but which also commonly damage co and seeds are discussed in other sections. These insects are, however, included in the key to flov and conelet damage.

Flower and conelet losses often are overlooked because the flowers and conelets are small and insects feeding upon them may be minute or inconspicuous.

INSECT OCCURRENCE ON HOST PINES

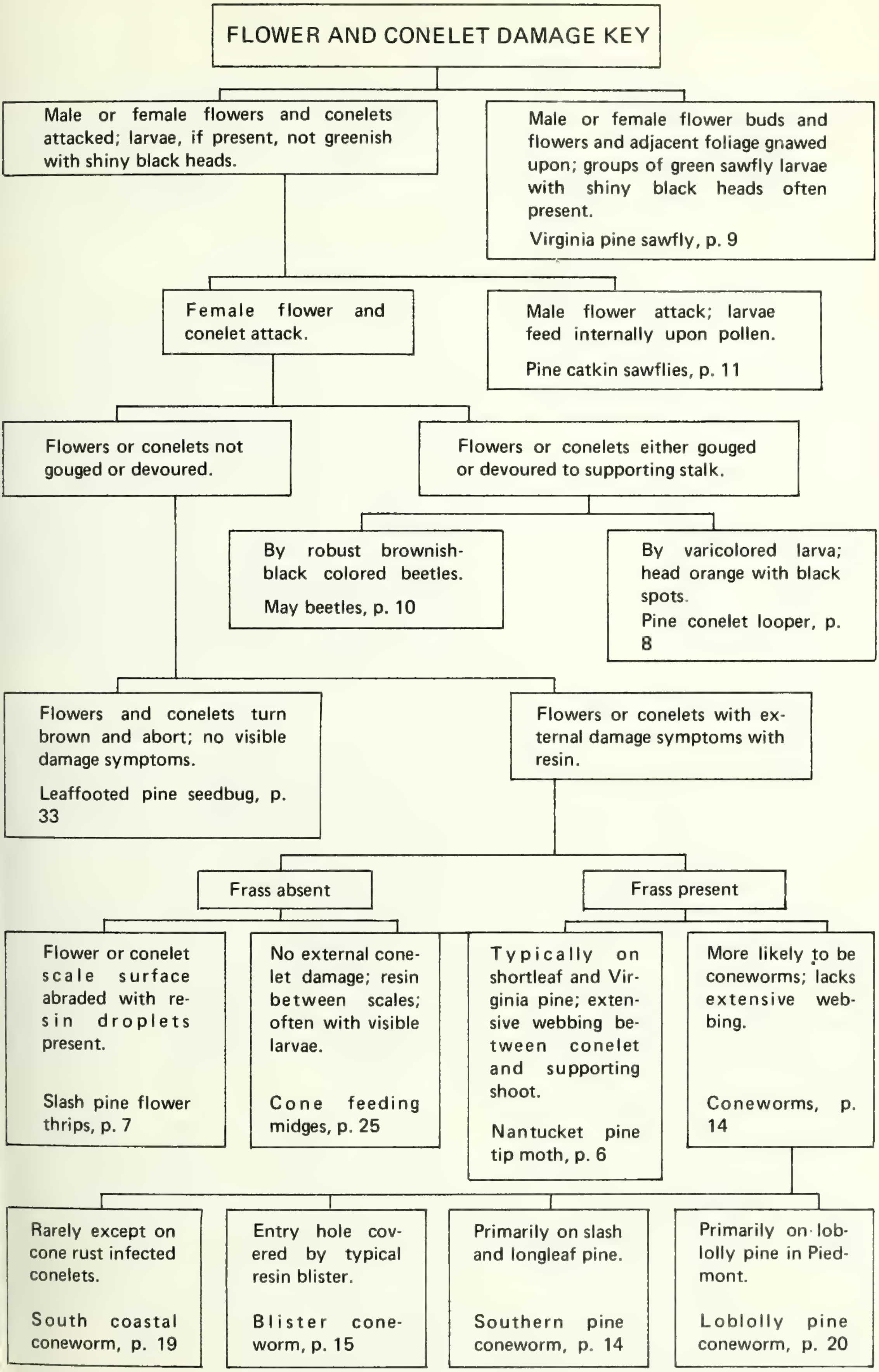
Flower and Conelet Damaging Insects

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Table Mour
Nantucket pine tip moth	No	Yes	Yes	No	Yes	No	N
Slash pine flower thrips	No	No	No	Yes	No	No	N
Pine conelet looper	No	Yes	Yes	Yes	?	No	N
Virginia pine sawfly	No	Yes	Yes	No	Yes	No	N
May beetles	?	?	Yes	?	?	?	
Pine catkin sawflies	Yes	Yes	Yes	Yes	Yes	Yes	
Leaffooted pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	Y
Cone feeding midges	Yes	Yes	Yes	Yes	Yes	?	
South coastal coneworm	Yes	No	Yes	Yes	No	No	N
Loblolly pine coneworm	Yes	Yes	Yes	Yes	Yes	No	
Southern pine coneworm	Yes	Yes	Yes	Yes	Yes	No	N
Blister coneworm	Yes	Yes	Yes	Yes	?	No	

INSECT ATTACK PERIODS

Flower and Conelet Damaging Insects

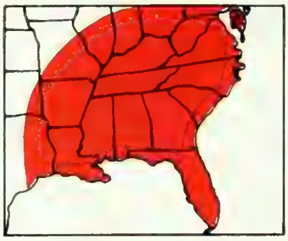
INSECT	FEEDING PERIOD										
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Nantucket pine tip moth				🟥	🟥	🟥					
Slash pine flower thrips	🟥	🟥									
Pine conelet looper		🟥	🟥	🟥	🟥	🟥					
Virginia pine sawfly				🟥	🟥	🟥					
May beetles			🟥	🟥							
Pine catkin sawflies	🟥	🟥	🟥	🟥	🟥						
Leaffooted pine seedbug				🟥	🟥	🟥	🟥	🟥	🟥	🟥	
Cone feeding midges		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	
South coastal coneworm			🟥	🟥	🟥	🟥					
Loblolly pine coneworm		🟥	🟥	🟥	🟥						
Southern pine coneworm		🟥	🟥	🟥							
Blister coneworm		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	



FLOWER AND CONELET DAMAGE KEY

- Male or female flowers and conelets attacked; larvae, if present, not greenish with shiny black heads.
  - Female flower and conelet attack.
    - Flowers or conelets not gouged or devoured.
      - Flowers and conelets turn brown and abort; no visible damage symptoms.
Leaffooted pine seedbug, p. 33
      - Flowers or conelets with external damage symptoms with resin.
        - Frass absent
          - Flower or conelet scale surface abraded with resin droplets present.
Slash pine flower thrips, p. 7
          - No external conelet damage; resin between scales; often with visible larvae.
Cone feeding midges, p. 25
        - Frass present
          - Typically on shortleaf and Virginia pine; extensive webbing between conelet and supporting shoot.
Nantucket pine tip moth, p. 6
          - More likely to be coneworms; lacks extensive webbing.
Coneworms, p. 14
            - Rarely except on cone rust infected conelets.
South coastal coneworm, p. 19
            - Entry hole covered by typical resin blister.
Blister coneworm, p. 15
            - Primarily on slash and longleaf pine.
Southern pine coneworm, p. 14
            - Primarily on loblolly pine in Piedmont.
Loblolly pine coneworm, p. 20
    - Flowers or conelets either gouged or devoured to supporting stalk.
      - By robust brownish-black colored beetles.
May beetles, p. 10
      - By varicolored larva; head orange with black spots.
Pine conelet looper, p. 8
  - Male flower attack; larvae feed internally upon pollen.
Pine catkin sawflies, p. 11
- Male or female flower buds and flowers and adjacent foliage gnawed upon; groups of green sawfly larvae with shiny black heads often present.
Virginia pine sawfly, p. 9

Nantucket pine tip moth, ***Rhyacionia frustrana*** **(Comstock) (2, 46, 49)**



BIOLOGY. — Moths emerge from overwintering pupae and their eggs on conelets or shoots in the early spring. There two to five generations per year depending on latitude. La injure shoots and buds, but only those of the first genera cause significant conelet mortality by feeding directly in an the flowers and conelets. Minor conelet attack may also o during the last generation in the fall.

INSECT IDENTIFICATION (fig. 1). — Forewing is marked with irregular brick-red and coffee-colored patches separated by a background of gray scales.

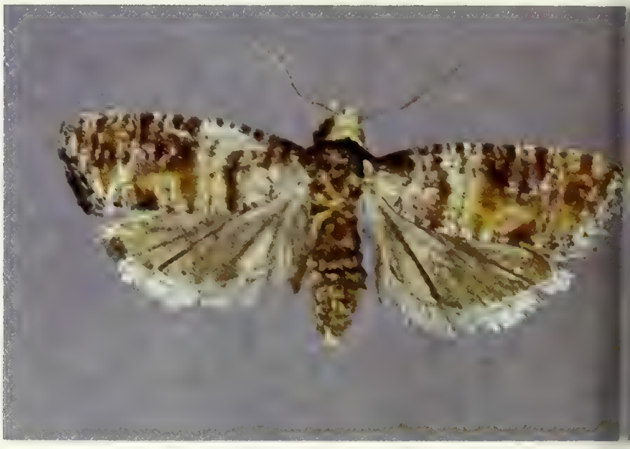


Figure 1. — Nantucket pine tip moth. (5X)

DAMAGE IDENTIFICATION (fig. 2). — A newly hatched Nantucket pine tip moth larva often bores into and destroys one or two conelets. Minute frass on the conelet surface is the first sign of larval boring. Later, a small quantity of resin often accumulates around or over the lesion. When older, the larva migrates to the supporting shoot or another conelet, laying down a loose network of webbing between the shoot and the adjacent injured conelet. A larva may also enter another shoot, killing it and any conelets it bears.

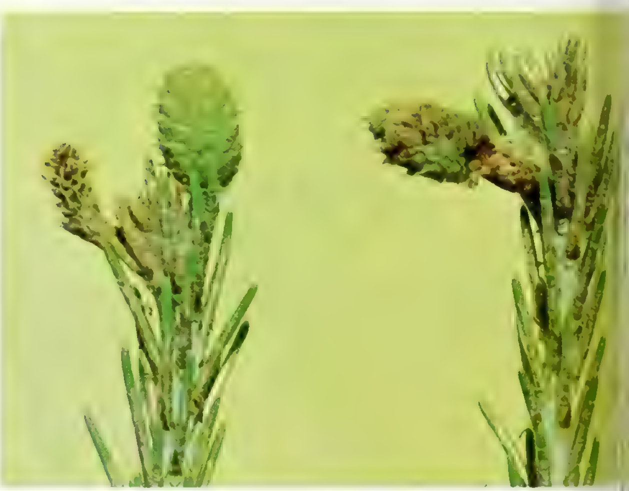
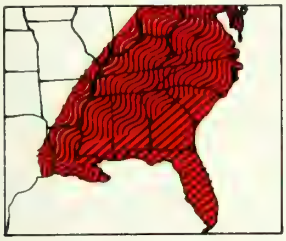


Figure 2. — Shortleaf pine conelets killed by Nantucket tip moth larvae. (1X)

IMPORTANCE. — Tip moths severely damage shoots in young pine plantations up to 3 meter (primarily loblolly, shortleaf, and Virginia pines) and often reduce the survival of outplanted gr stock during seed orchard establishment. In older orchards, tip moths infest shoots durin summer and fall, destroying buds containing embryonic flower primordia and thereby red flower production the following year. Direct attacks on shortleaf pine conelets often cause los 30 percent or more.

ash pine flower thrips, *Gnophothrips fuscus* (Morgan) (13, 18, 19)



BIOLOGY. — Knowledge of the life history of the slash pine flower thrips is incomplete. It is likely that this thrips occurs throughout the Eastern United States (see wavy area of distribution map). Injury to conelets, however, appears to be restricted to slash pine (see lined area of distribution map).

The slash pine flower thrips damages or kills female buds and flowers during a limited period from January through mid-February. The minute insects hide among the bracts or scales and are seldom visible. Pollinated flowers quickly become leathery enough to resist additional thrips feeding, but the more severely damaged conelets continue to abort. This thrips has also been noted on succulent new shoots of slash and loblolly pines during the summer.

NSECT IDENTIFICATION (fig. 3) — The adults are comparatively rge thrips, about 2 mm long, and very dark brown to black. They n be either winged or wingless.

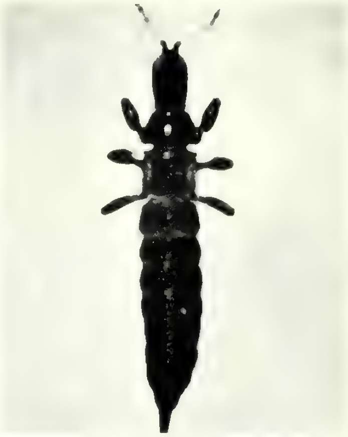


Figure 3. — Slash pine flower thrips. (25X)

AMAGE IDENTIFICATION (figs. 4 and 5). — Damaged female ower buds have resin flowing from wounds at the tips and between ne crevices formed by abutting vegetative buds. Severely damaged uds often abort.

Once the buds open, the thrips scrape the tender scales and bracts f the female flowers, leaving tiny, barely visible abrasions marked y beads of resin. Individual scales and bracts are often destroyed, d if damage is severe the flower shrivels and dies. Female flowers staining sublethal damage develop into mature cones the following ar, but these cones are crooked and gnarled, with areas of sunken, formed scales.

IMPORTANCE. — While the slash pine flower thrips damages and destroys female flowers only on slash pine, it is often very destructive in seed orchards of this species. Flower mortality as high as 45 percent has been recorded. In addition, both total and filled seed yields from cones that develop from flowers sustaining sublethal damage are often reduced by more than 50 percent.

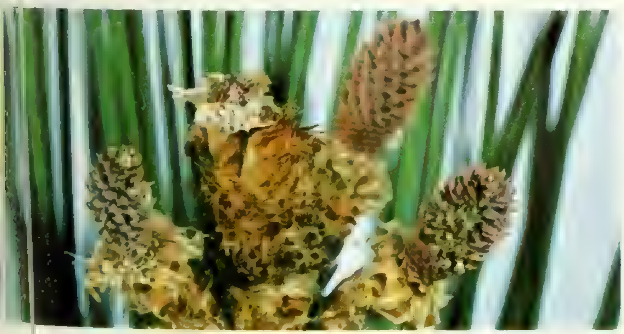


Figure 4. — Slash pine flower thrips damage to conelets. (1X)

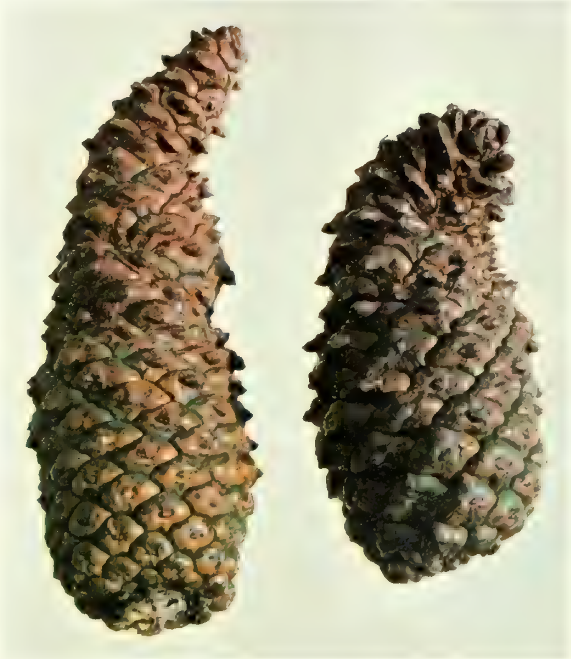
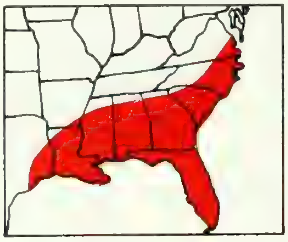


Figure 5. — Slash pine flower thrips damage on developed cones. (1X)

Pine conelet looper, ***Nepytia semiclusaria*** **(Walker) (11, 25)**



BIOLOGY. — The pine conelet looper has a single generatio per year. It overwinters as an egg, presumably under bark scale In early spring the eggs hatch and the larvae feed on the fema flowers of slash, loblolly, and shortleaf pines. On slash pine th larvae soon migrate to new needles, but on loblolly an shortleaf pines they continue to feed to maturity on the youn conelets. Larvae often retreat into the foliage when not feedin Pupation occurs in a flimsy web shelter among the needles, an adults emerge during the early summer (June in the Georg Piedmont).

INSECT IDENTIFICATION (figs. 6 and 7). — The mature larva of this looper is about 2.5 to 3.0 cm long, with an obvious brick-red dorsal stripe flanked by yellow stripes separated by a number of thin black and white lines. The orange head is marked with black spots. The moth is grayish-tan. Forewings are marked with two dark scalloped bands running front to back.

DAMAGE IDENTIFICATION (fig. 8). — Flowers or conelets injured by this looper are either gouged or completely devoured to the supporting stalk.

IMPORTANCE. — This insect is usually of minor importance but occasionally becomes epidemic and causes noticeable flower or conelet damage. Defoliation has been reported on sand pine.

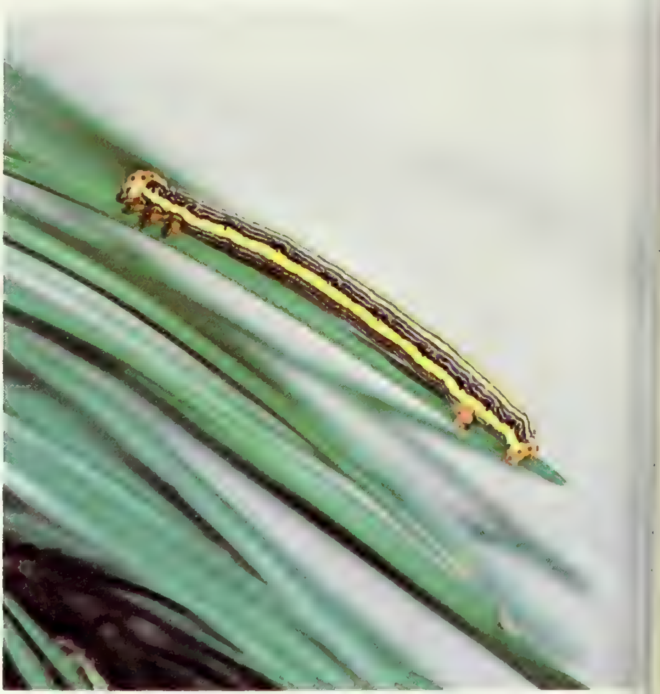


Figure 6. — Mature pine conelet looper larva. (3X)

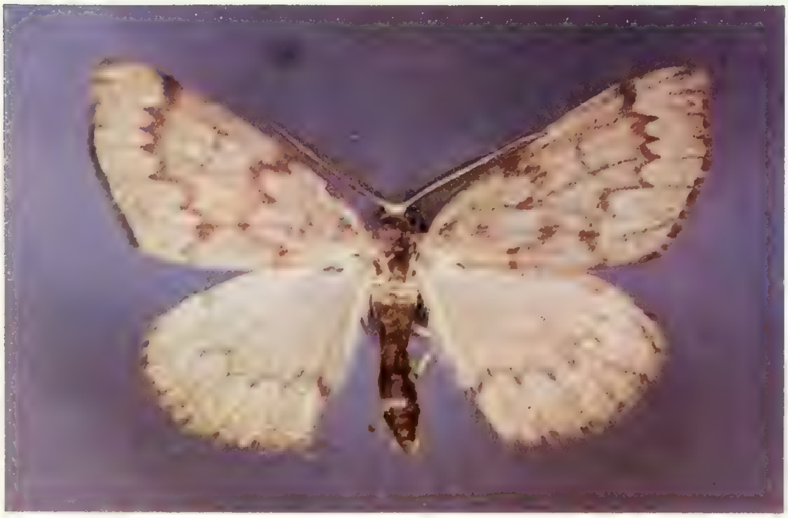


Figure 7. — Pine conelet looper. (3X)

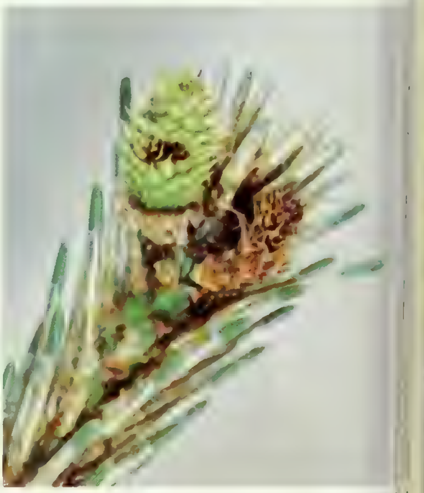
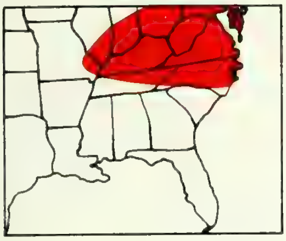


Figure 8. — Pine conelet looper-k shortleaf pine conelets. (1X)

Virginia pine sawfly, *Neodiprion pratti pratti* **(Dyar) (1, 3, 11)**



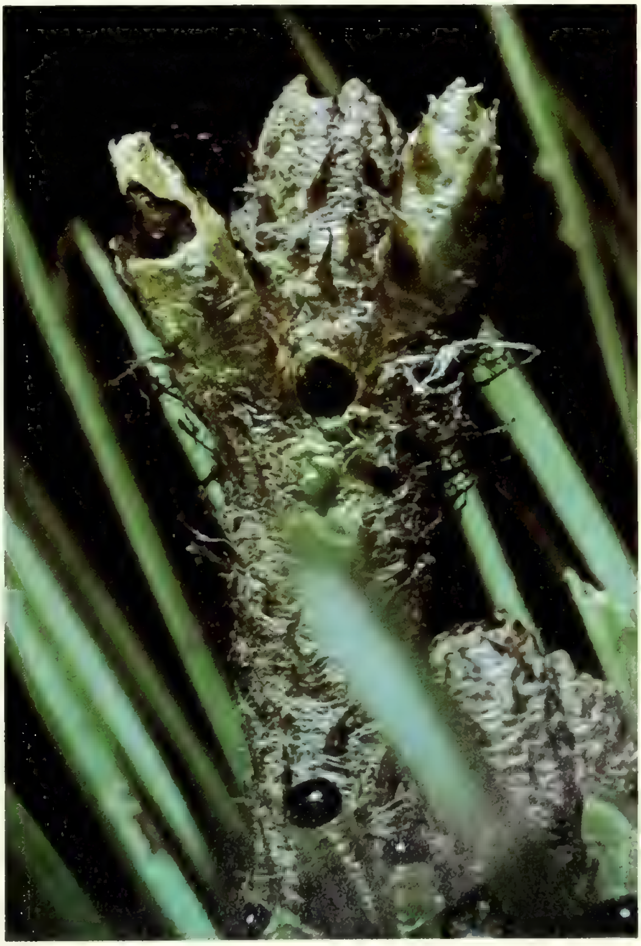
BIOLOGY. – The Virginia pine sawfly is the only sawfly known to damage pine strobili. There is one generation a year. Winter is spent in the egg stage. In the early spring, eggs hatch and the larvae feed in groups on the previous year's needles. Small larvae also devour buds, flowers, and the tender bark of twigs. Full-grown larvae drop to the ground and pupate in the soil. Adults emerge in late fall and deposit eggs in slits along the needles.

INSECT IDENTIFICATION (fig. 9). – Newly hatched larvae are pale green with shiny black head capsules. Full-grown larvae are spotted or marked with longitudinal black stripes. They are from 16 to 23 mm long. Adults are seldom seen.

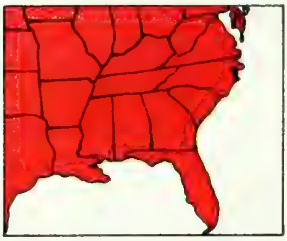
DAMAGE IDENTIFICATION (fig. 9). – Large portions of unopened flower buds or flowers are eaten away; obvious foliage feeding leaves tufts of needle bases.

IMPORTANCE. – From 3 to over 9 percent of the shortleaf pine flower crop has been destroyed when sawfly populations were low. Much greater mortality of female flowers can probably be expected during sawfly epidemics.

Figure 9. – Virginia pine sawfly-killed Virginia pine flower buds. (3X)



May beetles, *Phyllophaga* spp. (1, 11, 35)



BIOLOGY. – Adults, commonly called May or June beetles feed nocturnally on the foliage of various pines and hardwoods One species, *P. micans* (Knoch), however, has been reported as damaging conelets of loblolly pine. Eggs are laid in small groups in the soil at depths of 7 to 18 cm. The larvae, commonly called white grubs, are root feeders. After feeding for 1 to 3 years they pupate and emerge as adults in the spring or summer.

INSECT IDENTIFICATION (fig. 10). – Adults are robust beetles 15 to 17 mm long. Wing covers are dull brownish-black.

DAMAGE IDENTIFICATION (fig. 10). – Adult May beetle feeding often leaves only the conelet stalk intact. This injury is indistinguishable from that caused by the pine conelet looper.

IMPORTANCE. – The impact of these insects on southern pine conelet crops is unknown. Damage has only been reported from central Louisiana. While only one species is recorded as causing this damage, other May beetles with similar biologies and habits may also damage conelets.

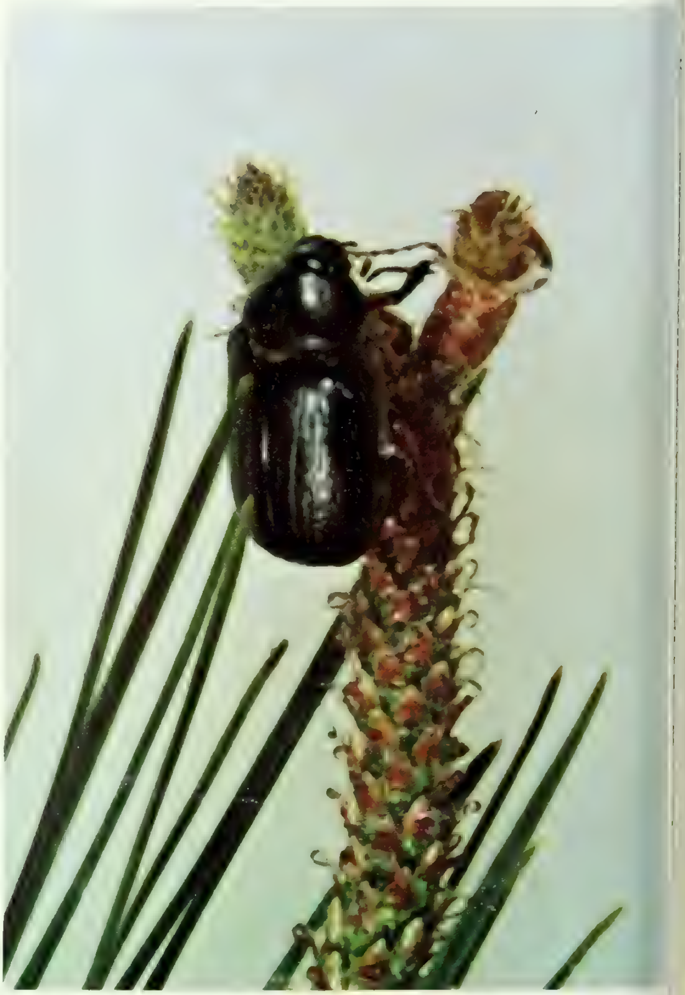
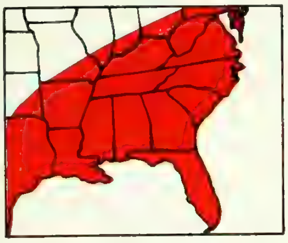


Figure 10. – May beetle adult feeding on loblolly pine flowers. (3X

ine catkin sawflies, *Xyela* spp. (4, 22, 30)



BIOLOGY. – The pine catkin sawflies have one generation per year. Adults emerge from pupae in the soil (December-February in northern Florida) and lay their eggs in male flower (catkin) buds of pines. The larvae feed within the male flowers on pollen. Larval development is synchronized with maturation of male flowers, and the larvae drop to the ground during pollen shed, remain dormant in the soil until winter, then pupate. Pine catkin sawfly species include *Xyela bakeri* Konow, *X. minor* Norton, *X. obscura* (Strobl), and probably *X. dodgei* Greenbaum.

NSECT IDENTIFICATION (fig. 11). – The larvae are commonly observed in pollen extracted for ine breeding work. They are small white grubs 3 to 5 mm long. The adults are about 3 mm long ut are seldom seen.

AMAGE IDENTIFICATION. – Infested male flowers are often distorted and bear small white pots of dried resin on the surface.

MPORTANCE. – Larval damage undoubtedly reduces the amount of viable pollen; however, this ss is usually tolerable. Effect on viability of stored pollen has not yet been studied.

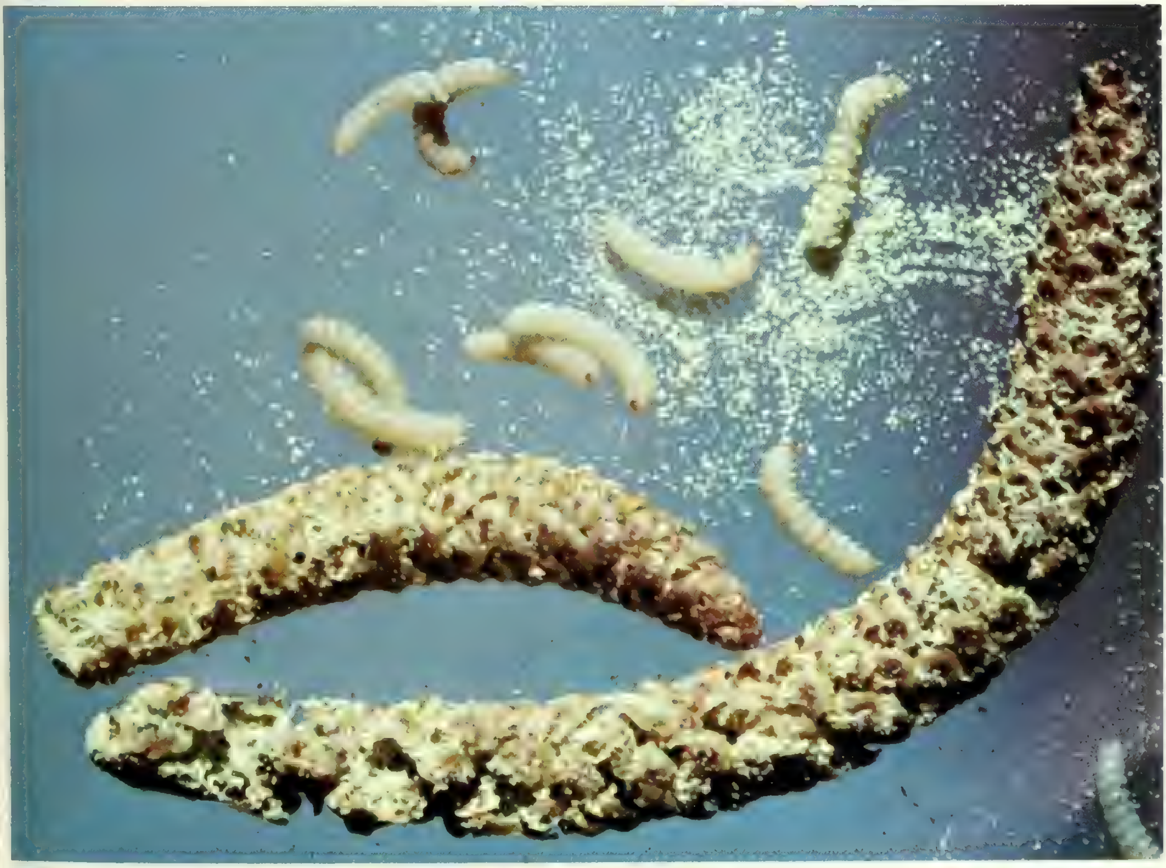


Figure 11. – Pine catkin sawfly larvae emerging from drying pine catkins. (3X)

CONE DAMAGE

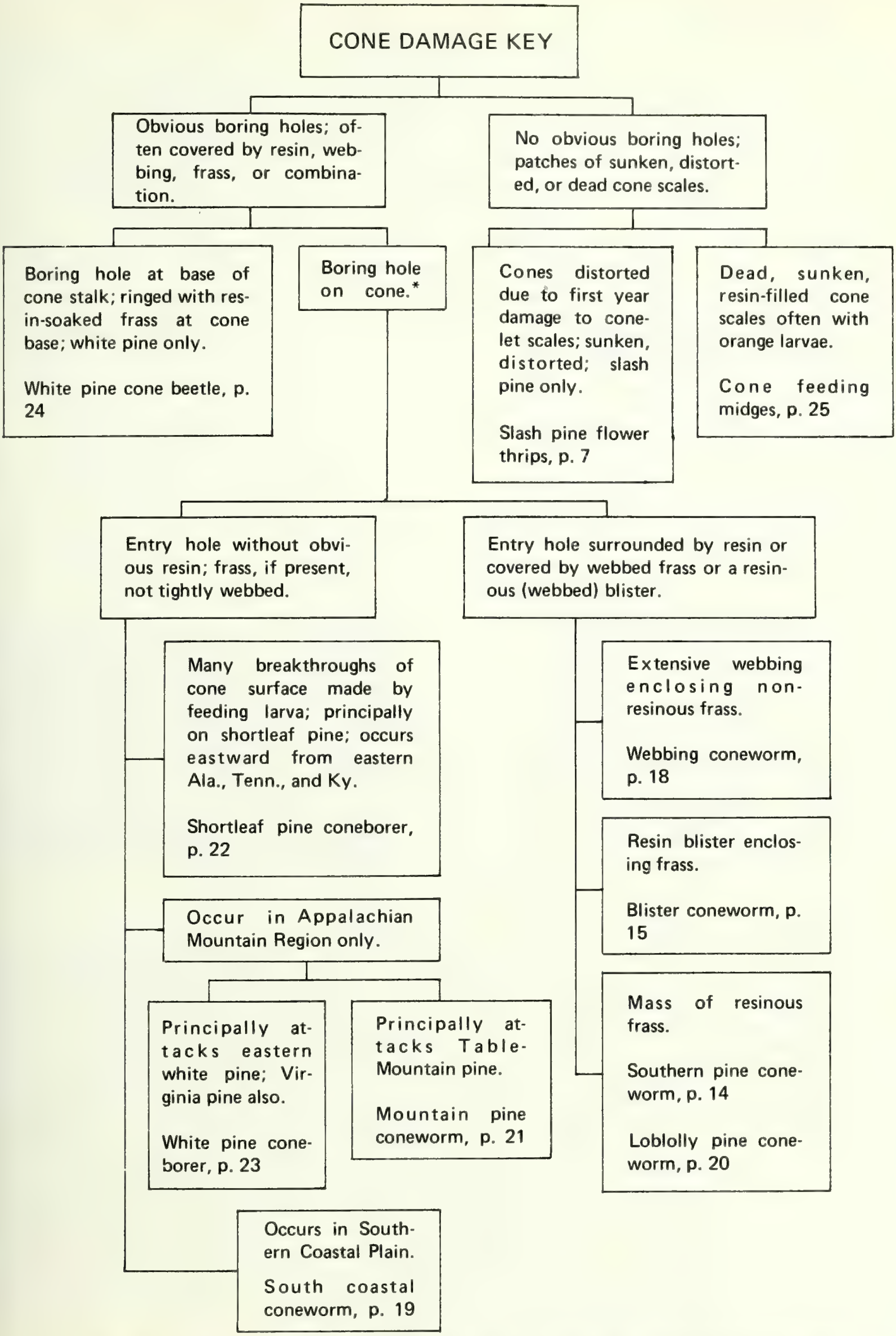
Several kinds of larvae feed by tunneling into and within cones. Characteristically, pellets of fra (excrement) are deposited within or on the cone, often mingled with obvious strands of silk webbing. Attacked cones are easily noticed because all or parts of the cones turn brown. Su cone-damaging insects belong to two moth families, the Phycitidae (*Dioryctria* spp.) and t Olethreutidae (*Eucosma* spp.), and one beetle family, the Scolytidae *(Conophthorus* spp.). Seve genera of midge flies in the family Cecidomyiidae also kill or damage cones by less obvious interr feeding.

Cone Damaging Insects

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Table Moun
Southern pine coneworm	Yes	Yes	Yes	Yes	Yes	No	N
South coastal coneworm	Yes	No	Yes	Yes	No	No	N
Webbing coneworm	No	Yes	Yes	No	Yes	?	
Blister coneworm	Yes	Yes	Yes	Yes	?	No	
Mountain pine coneworm	No	?	Yes	No	?	No	Y
Loblolly pine coneworm	Yes	Yes	Yes	Yes	Yes	No	
Shortleaf pine coneborer	No	Yes	Yes	No	?	No	
White pine coneborer	No	No	No	No	Yes	Yes	N
White pine cone beetle	No	No	No	No	?	Yes	N
Cone feeding midges	Yes	Yes	Yes	Yes	Yes	?	

Cone Damaging Insects

INSECT	FEEDING PERIOD										
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Southern pine coneworm					🟥	🟥	🟥	🟥	🟥	🟥	🟥
Blister coneworm		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Webbing coneworm				🟥	🟥	🟥					
South coastal coneworm						🟥	🟥	🟥	🟥		
Loblolly pine coneworm					🟥	🟥	🟥				
Mountain pine coneworm							🟥	🟥	🟥		
Shortleaf pine coneborer					🟥	🟥	🟥				
White pine coneborer							🟥	🟥			
White pine cone beetle					🟥	🟥	🟥	🟥	🟥		
Cone feeding midges				🟥	🟥	🟥	🟥	🟥	🟥	🟥	



CONE DAMAGE KEY

Obvious boring holes; often covered by resin, webbing, frass, or combination.

Boring hole at base of cone stalk; ringed with resin-soaked frass at cone base; white pine only.

White pine cone beetle, p. 24

Boring hole on cone.*

Entry hole without obvious resin; frass, if present, not tightly webbed.

Many breakthroughs of cone surface made by feeding larva; principally on shortleaf pine; occurs eastward from eastern Ala., Tenn., and Ky.

Shortleaf pine coneborer, p. 22

Occur in Appalachian Mountain Region only.

Principally attacks eastern white pine; Virginia pine also.

White pine coneborer, p. 23

Principally attacks Table-Mountain pine.

Mountain pine coneworm, p. 21

Occurs in Southern Coastal Plain.

South coastal coneworm, p. 19

Entry hole surrounded by resin or covered by webbed frass or a resinous (webbed) blister.

Extensive webbing enclosing non-resinous frass.

Webbing coneworm, p. 18

Resin blister enclosing frass.

Blister coneworm, p. 15

Mass of resinous frass.

Southern pine coneworm, p. 14

Loblolly pine coneworm, p. 20

No obvious boring holes; patches of sunken, distorted, or dead cone scales.

Cones distorted due to first year damage to conelet scales; sunken, distorted; slash pine only.

Slash pine flower thrips, p. 7

Dead, sunken, resin-filled cone scales often with orange larvae.

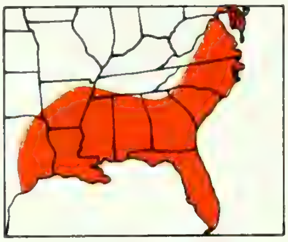
Cone feeding midges, p. 25

For additional help in identifying these borers see Key and drawings of coneboring caterpillars on page 26 and figures 20 & 21 showing larvae and moths.

Pine Coneworms (*Dioryctria* spp.)

Damage consists of larval tunnels or partly to totally excavated areas within the infested cones. Some coneworms also feed in buds, shoots, flowers, and conelets. Six coneworm species are known to damage southern pines.

Southern pine coneworm, *Dioryctria amatella* **(Hulst) (7, 8, 20, 21, 24, 27, 29, 32, 39, 40, 41, 50, 51)**



BIOLOGY. — The southern pine coneworm has several generations per year with much overlapping of life stages. Male and female pine flowers, galls caused by fusiform rust (*Cronartium fusiforme* Hedge. & Hunt ex. Cumm.), injured tree stems, and cones may be infested. On slash and longleaf pines, early-season infestations tend to occur in flowers and shoots, in cones infected by southern cone rust (*Cronartium strobilinum* (Arth Hedg. & Hahn), and in fusiform rust galls. These larvae, except in gall infestations, often move on to complete development in cones. Fusiform rust galls sustain larvae through pupation. Second and subsequent generations of larvae develop primarily in cones. Early-season infestations of loblolly pine seem to be in fusiform rust galls, but succeeding generations infest the cones of loblolly and associated pines. Pupation occurs within the infested material. Larvae, usually first instars, overwinter.

INSECT IDENTIFICATION (figs. 20a and 21a). — Mature larvae of the southern pine coneworm are somewhat variable in color, but tend toward dark purplish-brown above and nearly white beneath, with greenish tints especially in prepupal larvae. Dark elevated areas bearing setae and black bead-like patterns of small depressions are obvious on abdominal segments (fig. 19c).

Adults are dark brown, often appearing nearly black, with contrasting distinct white markings.

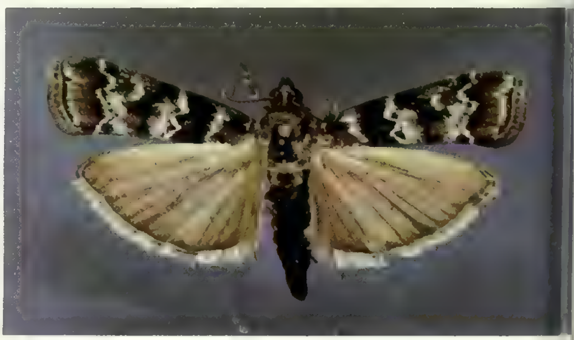


Figure 21a. — Southern pine coneworm. (2X)

DAMAGE IDENTIFICATION (fig. 12a). — A mixture of resin and frass is usually present on the surface of infested material, but resin may be scant or absent from maturing cones.

IMPORTANCE. — This coneworm is prevalent throughout the Southeast and is consistently one of the most serious pests of pine cones.

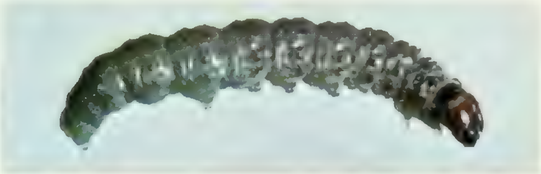


Figure 20a. — Southern pine coneworm. (2½X)

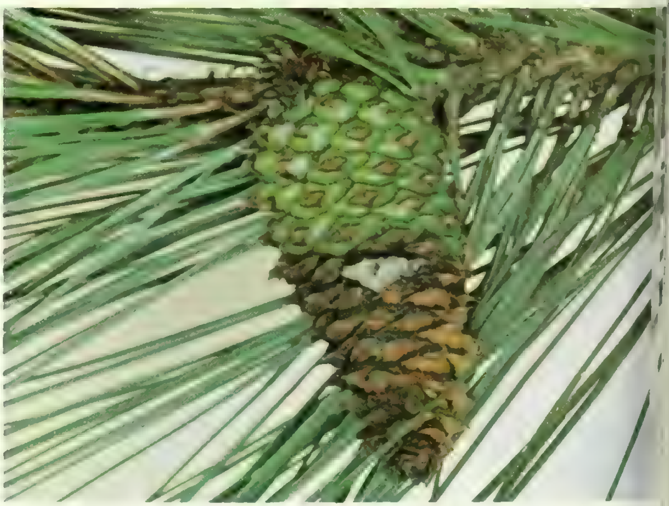
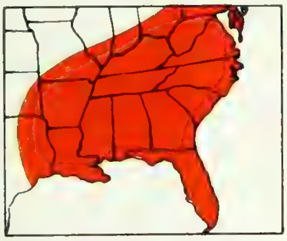


Figure 12a. — Southern pine coneworm damage to loblolly pine cone. (½X)

Blister coneworm, *Dioryctria clarioralis* **(Walker) (21, 27, 32, 40, 41, 50, 51)**



BIOLOGY. — The blister coneworm has three distinct generations per year in the Middle to Deep South. Flowers, buds, and shoots, as well as conelets and young cones, are attacked. Mature larvae migrate from the infested material to pupate on twigs in thin cocoons covered with bits of shoot scales.

NSECT IDENTIFICATION (figs. 20f and 21f). — Mature blister coneworm larvae are easily recognized by their brownish-orange color, which is often tinged with gray above and is paler beneath. Beadlike patterns of small pits are only moderately obvious on abdominal segments (fig. 19d).

The moth is also distinctive; each forewing has a wide dark brownish-black band near the wing base. The remainder of this wing is shaded in tones of brown to black with grayish-white crosslines and markings.

DAMAGE IDENTIFICATION (fig. 12b). — Infestd material has a very typical silk and resin blister, illed with frass, covering the entry hole. Infested uds or conelets are usually completely hollowed ut.

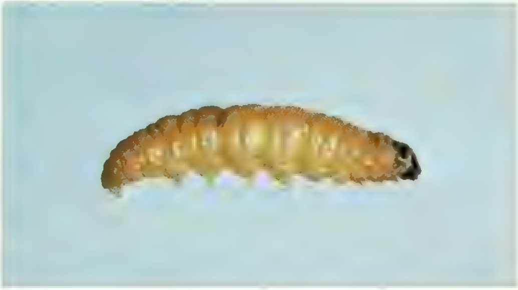


Figure 20f. — Blister coneworm. (2X)

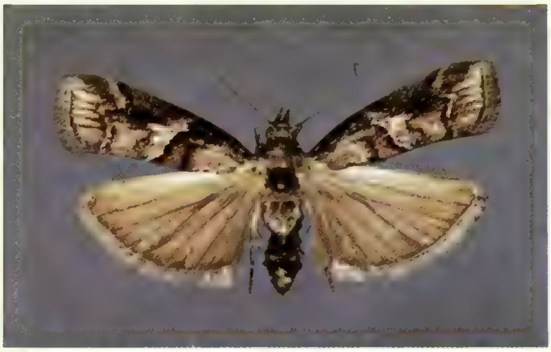


Figure 21f. — Blister coneworm. (2X)

MPORTANCE. — The blister oneworm seems of lesser importance than most coneworm pecies. It often occurs on ongleaf pine but feeds in buds nd shoots as well as conelets. his feeding pattern tends to minimize losses of conelets.

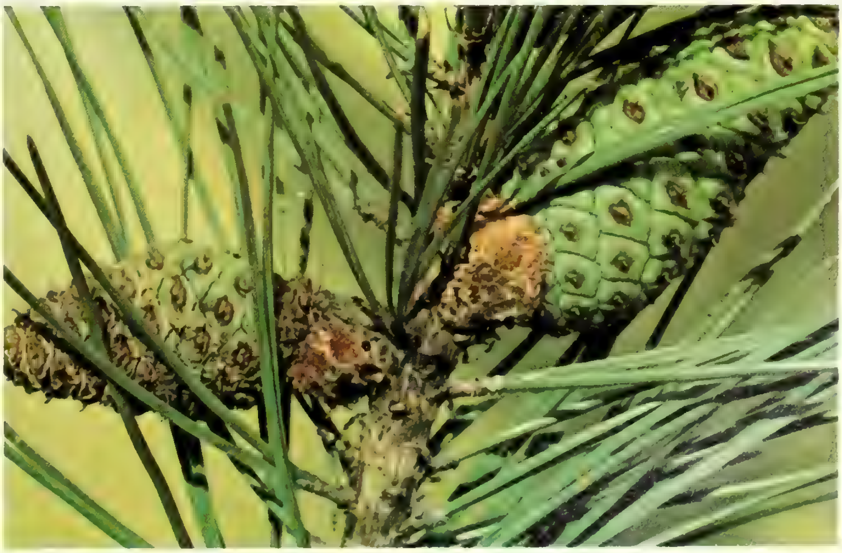


Figure 12b. — Blister coneworm damage to shortleaf pine cones.

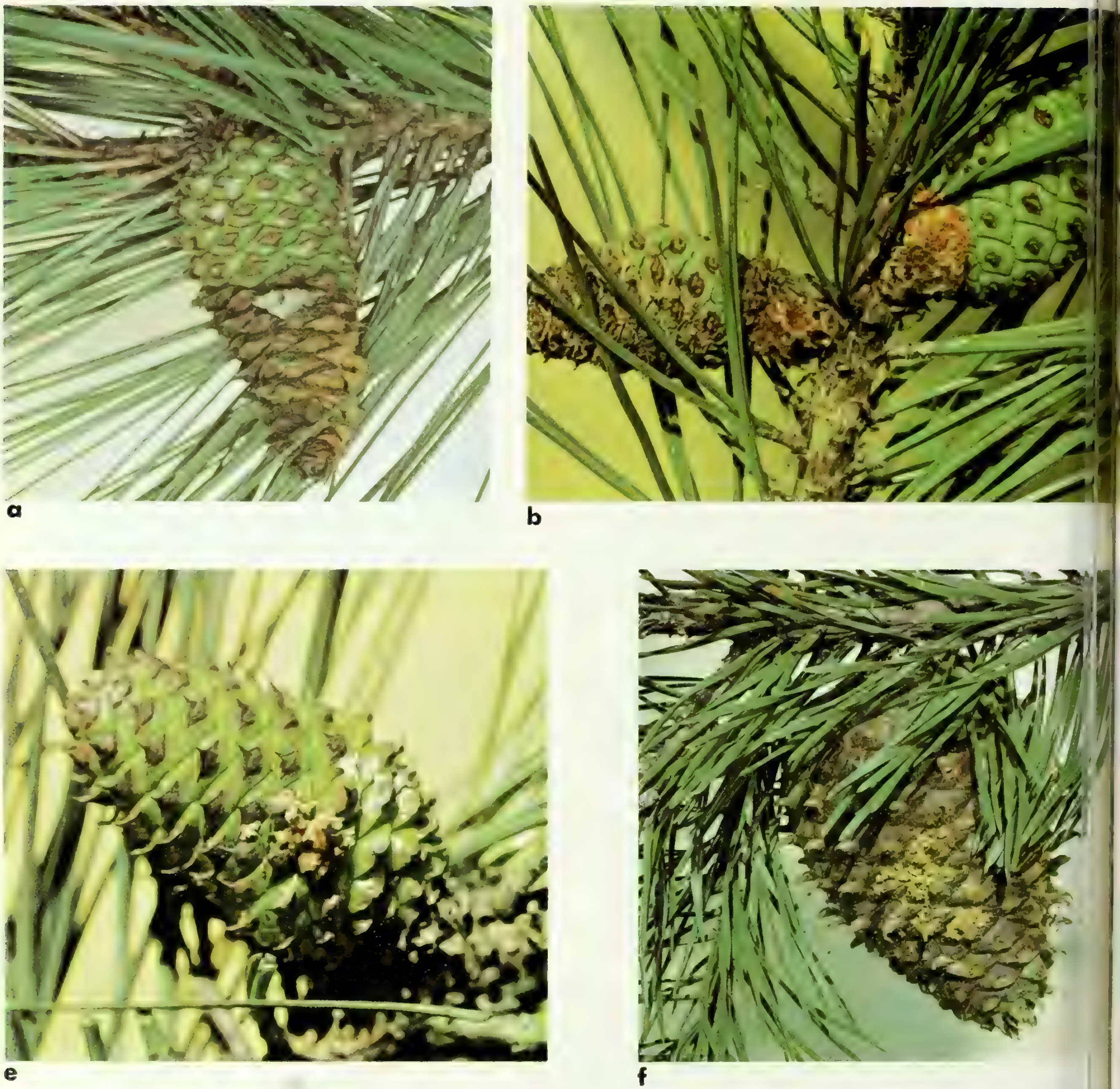
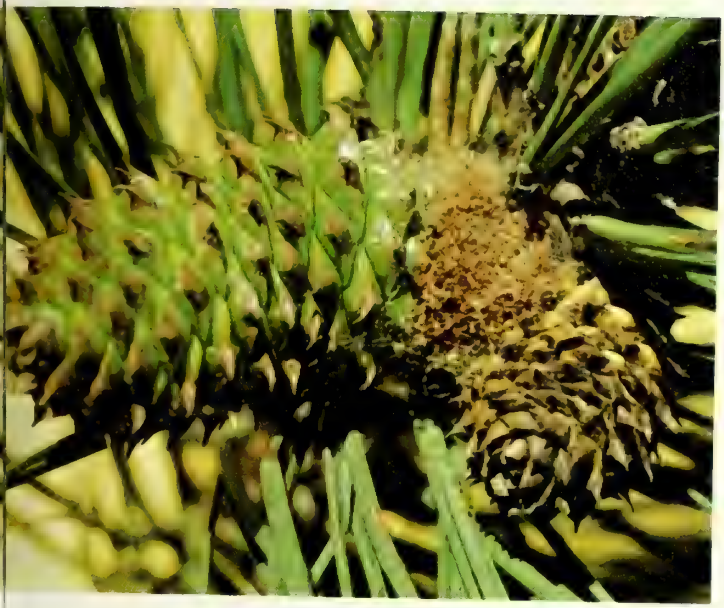
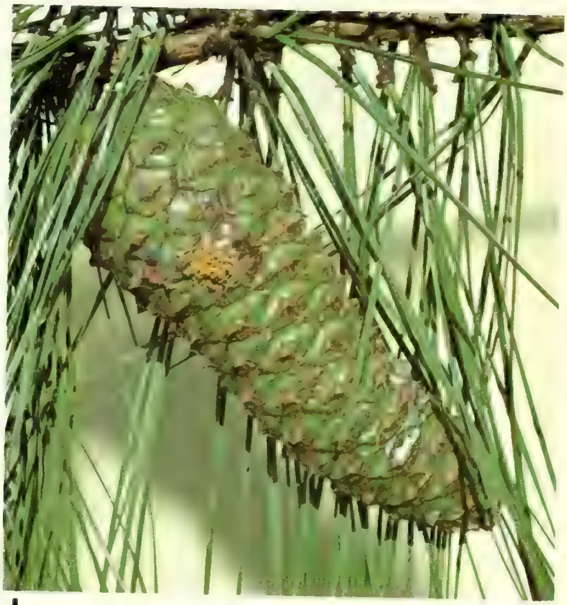


Figure 12. — Coneworm damage: (a) southern pin worm damage to loblolly pine cone; (b) Blister cor damage to shortleaf pine cones; (c) webbing cor damage to loblolly pine cones; (d) south coastal cor damage to loblolly pine cone; (e) loblolly pine cor damage to loblolly pine cone; (f) mountain pine cor damage to Table-Mountain pine cone; (g) loblolly pi worm damage to loblolly pine conelet; (h) shortle coneborer damage to shortleaf pine cones; (i) whit coneborer damage to eastern white pine cones. (1X)





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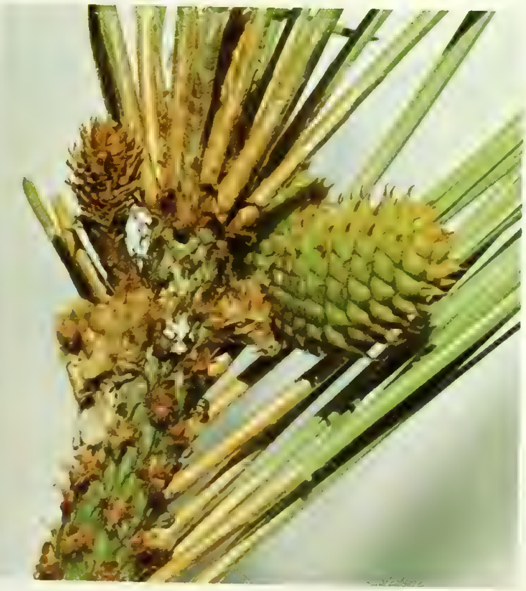

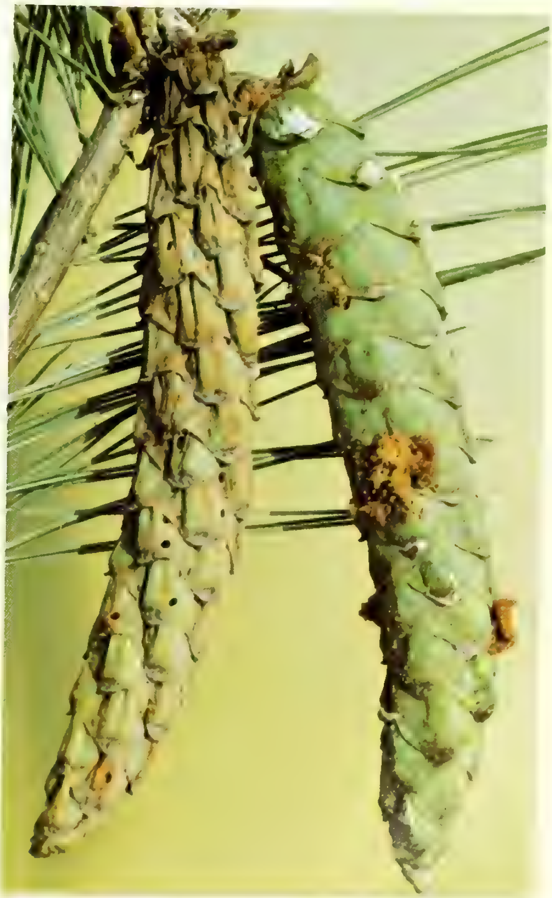

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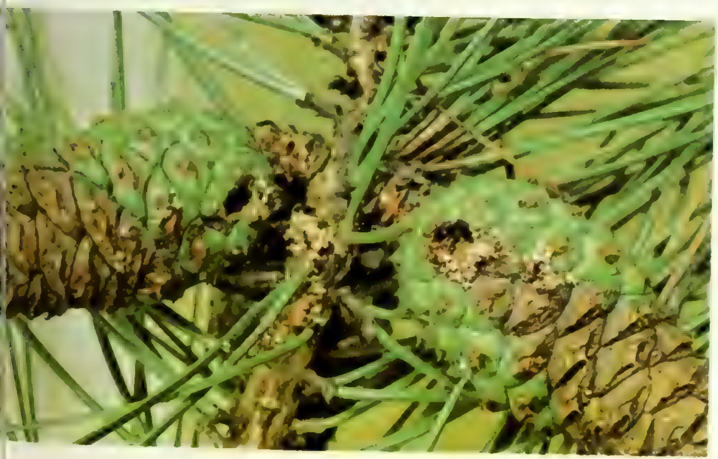
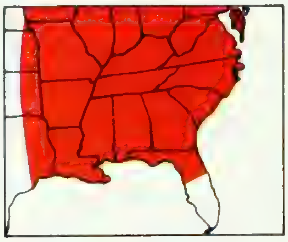


Webbing coneworm, ***Dioryctria disclusa*** **(Heinrich) (21, 27, 32, 34, 40, 41, 50, 51)**



BIOLOGY. – The webbing coneworm has a single generatio per year. Moths emerge in late spring and early summer in th Georgia Piedmont, but absence of apparent damage until th following spring suggests that young (early-stage) larvae remai in diapause. Presumably, young larvae infest male flower Cones are infested early in the growing season, when olde larvae are found to be present. Mature larvae pupate in the ho cone behind a network of silken threads across the larval hol

INSECT IDENTIFICATION (figs. 20e and 21e). – Larvae of the webbing coneworm a grayish-buff above, paling beneath. Seta-bearing elevations are pale, while the dark beadlike pattern of pits are moderately noticeable (as in the blister coneworm) (fig. 19d).

Moths have striking yellow to orange-colored forewings, with sharp white crossbands an markings.

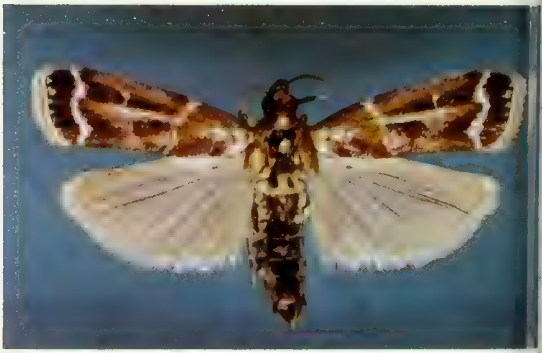


Figure 21e. – Webbing coneworm. (2X)

DAMAGE IDENTIFICATION (fig. 12c). – Infested cones have a characteristic mass of heavily webbed frass, similar to that produced by the pine webworm (*Tetralopha robustella* Zeller) over the larval entry hole. Internally, the infested cones are nearly to completely hollowed out and often contain much silken material.

IMPORTANCE. – The webbing coneworm is occasionally abundant, causing moderate losses of Virginia and loblolly pine cones in the South.

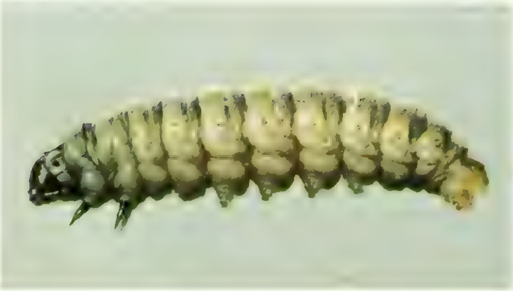


Figure 20e. – Webbing coneworm. (3X)

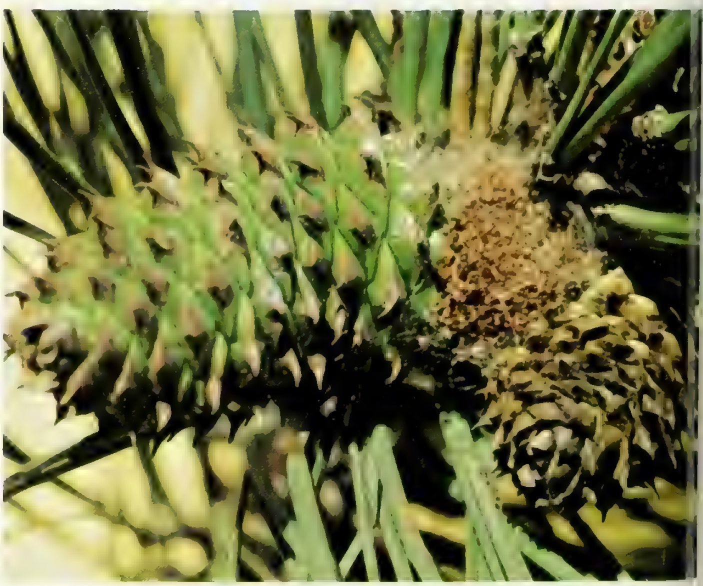
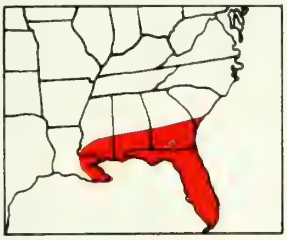


Figure 12c. – Webbing coneworm damage to loblolly pine cone. (1X)

South coastal coneworm, ***Dioryctria*** **new species (*abietella* group)[5] (21, 40, 51)**



BIOLOGY. — The south coastal coneworm has repeated generations per year, possibly as many as six in Florida. Spring infestations occur in conelets infected by southern cone rust. During the summer and early fall, cones are infested. An overwintering infestation occurs in fusiform rust galls and infrequently in shoot material.

INSECT IDENTIFICATION (figs. 20b and 21d). — Larvae of the south coastal coneworm are reddish-purple above, paling beneath, and with greenish tints especially in fully mature larvae. Abdominal seta-bearing elevations are brown, not conspicuous; pit patterns are pale, inconspicuous (fig. 19d).

The forewings of the moths have white crossbands and markings which blend into the gray background. A pair of pale-yellow spots occurs about midway along the hind margin of the forewing. Raised tufts of scales, characteristic of many coneworm species, are lacking in this species as well as in the webbing coneworm.

DAMAGE IDENTIFICATION (fig. 12d). — Infested cones generally have only frass pushed to the surface through entry holes. The south coastal coneworm is frequently a secondary invader of previously damaged cones, such as those infested by the southern pine coneworm. Internally, the damage is a maze of galleries.

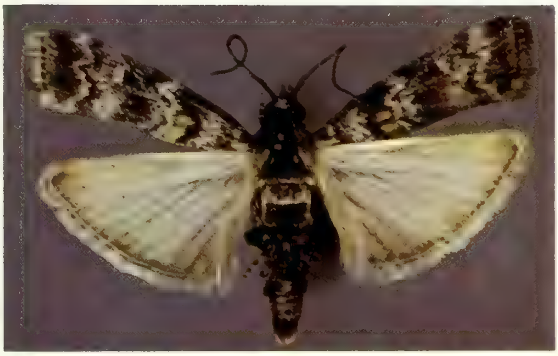


Figure 21d. — South coastal coneworm. (2X)

IMPORTANCE. — The rather limited distribution of this species, its spring association with diseased conelets, plus a tendency to secondarily infest damaged cones, suggest that it be considered of less importance than the southern pine coneworm. However, it appears to become more prevalent in maturing cones where it obviously causes primary destruction.

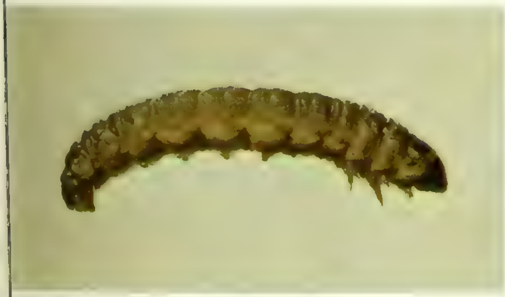


Figure 20b. — South coastal coneworm.

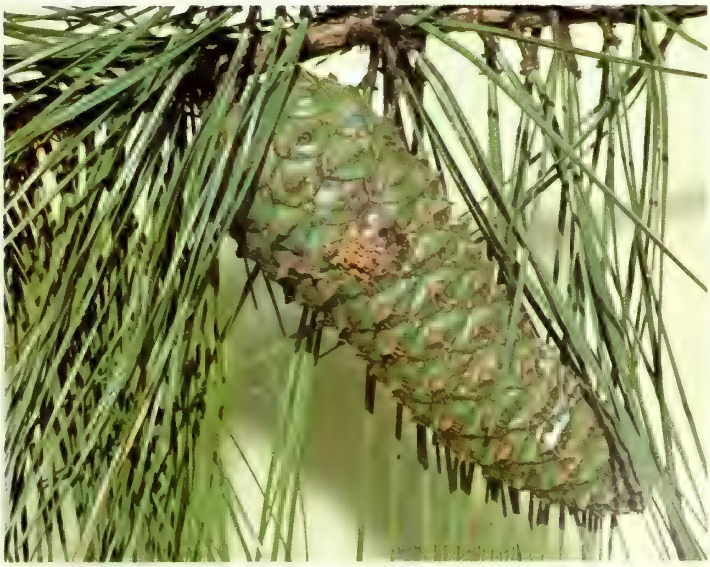


Figure 12d. — South coastal coneworm damage to loblolly pine cone. (1X)

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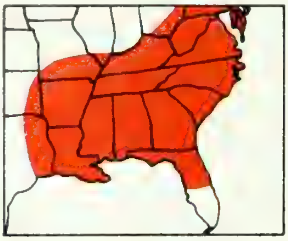
[5] *This is a yet undescribed* Dioryctria *species of the* abietella *group. It has appeared in the literature as* D. abietella *D. & S. and* D. abietivorella *(Grote) in previous reports from the Southeastern United States.*

Loblolly pine coneworm, *Dioryctria* new species (*zimmermani* group)[6] (9, 24, 27, 50)



BIOLOGY. — The loblolly pine coneworm has one generati per year. Young larvae overwinter, then infest flowers a shoots. Some larvae complete development in this host materi in slash and longleaf pines; others migrate into cones. loblolly, shortleaf, and Virginia pines, most, if not all, larv finish feeding in the cones. The mature larvae remain inacti over the summer, and pupation and adult emergence occur fro August to October.

INSECT IDENTIFICATION (figs. 20d and 21c). — Mature larvae of the loblolly pine coneworm resemble the southern pine coneworm but are dark bluish-black above and blue-green beneath.

The moths are also similar to those of the southern pine coneworm, but the base color of the forewing tends more toward a medium brown with irregular patches of rust-brown. The crossbanding and other pale markings are grayish, subtly blending into medium brown.

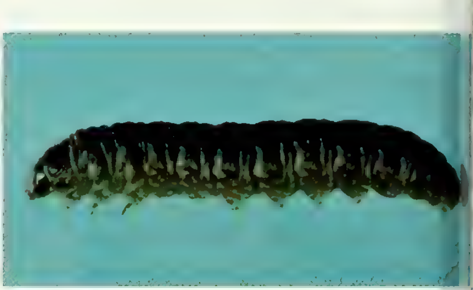


Figure 20d. — Loblolly pine coneworm. (2

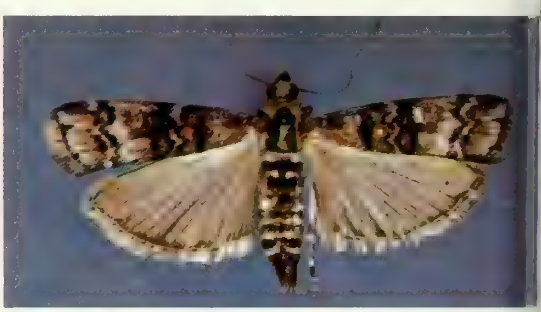


Figure 21c. — Loblolly pine coneworm. (2X)

DAMAGE IDENTIFICATION (figs. 12e and 13). — Damage to flowers, shoots, and cones by the loblolly pine coneworm resembles closely that of the southern pine coneworm. Spring and early summer cone infestations on loblolly, shortleaf, and Virginia pines may be attributed to the loblolly pine coneworm, but damage by the two species cannot be separated on slash and longleaf pines.

IMPORTANCE. — Shoot attacks followed by cone infestations are common, particularly on loblolly pine. On this species, the loblolly pine coneworm seems to approach the southern pine coneworm in importance.

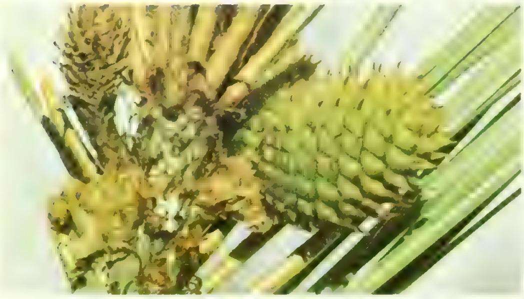


Figure 13. — Loblolly pine coneworm damage to loblolly pine conelet. (1X)

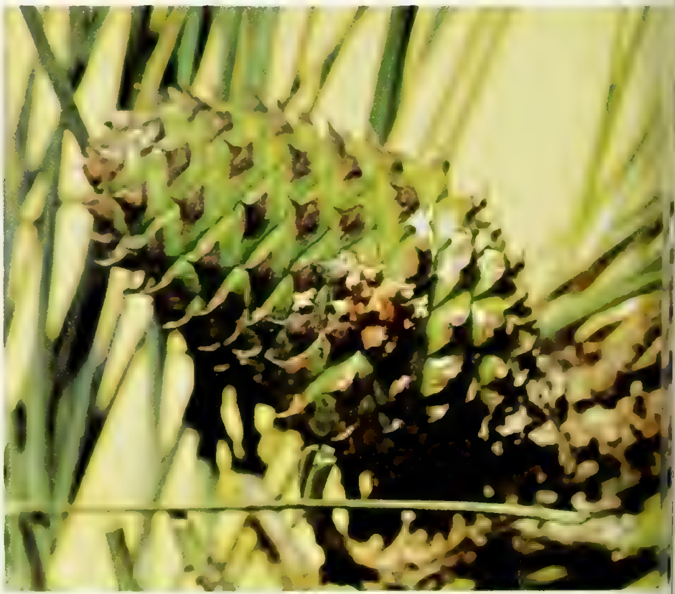


Figure 12e. — Loblolly pine coneworm damage to loblolly pine cone. (1X)

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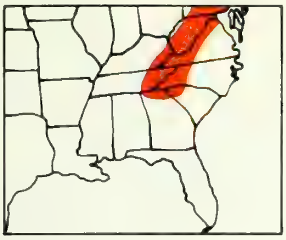
[6] *This is a yet undescribed* Dioryctria *species of the* zimmermani *group. It has appeared in the literature as* zimmermani *(Grote) in previous reports from the Southeastern United States.*

Mountain pine coneworm, *Dioryctria taedae* Schaber and Wood (24)



BIOLOGY. — Little is known about the mountain pine coneworm, which was only recently recognized as a new species. It attacks primarily Table-Mountain pine cones and rarely those of loblolly pine. Pupation occurs in the infested cones, and the moths emerge in late summer and early fall (August-September). The complete life cycle is unknown.

NSECT IDENTIFICATION (figs. 20c and 21b). — Larvae of the mountain pine coneworm resemble those of the southern pine coneworm but are off-white to pale green, usually tinted light purplish-pink on the upper urfaces.

Moths are variable in color. Forewings are slate gray o mixed gray and brown with white crossbands and diffuse markings somewhat similar to those of the south oastal coneworm. Raised tufts of strongly reflexed cales on the forewings of this coneworm separate it rom the south coastal coneworm. Hind wings are pale an, shaded gray at the margins.

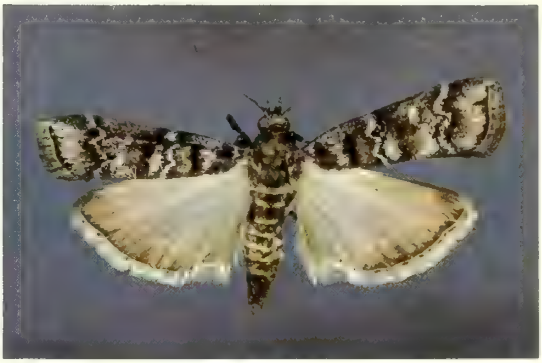
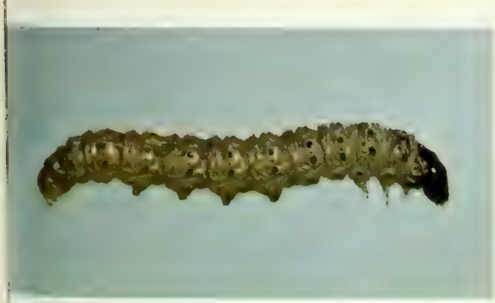


Figure 21b. — Mountain pine coneworm. (2X)

DAMAGE IDENTIFICATION (fig. 12f). — Maturing larvae infesting Table-Mountain pine cones produce noticeable reaks in the cone surface in addition to he entry holes. Frass accumulations, ghtly webbed, are often piled up on the pper cone surfaces and lodged between ones.

MPORTANCE. — This insect is ap-arently prevalent only on Table-Mountain pine, and occasionally occurs ocally in destructive abundance.



igure 20c. — Mountain pine coneworm. (2½X)

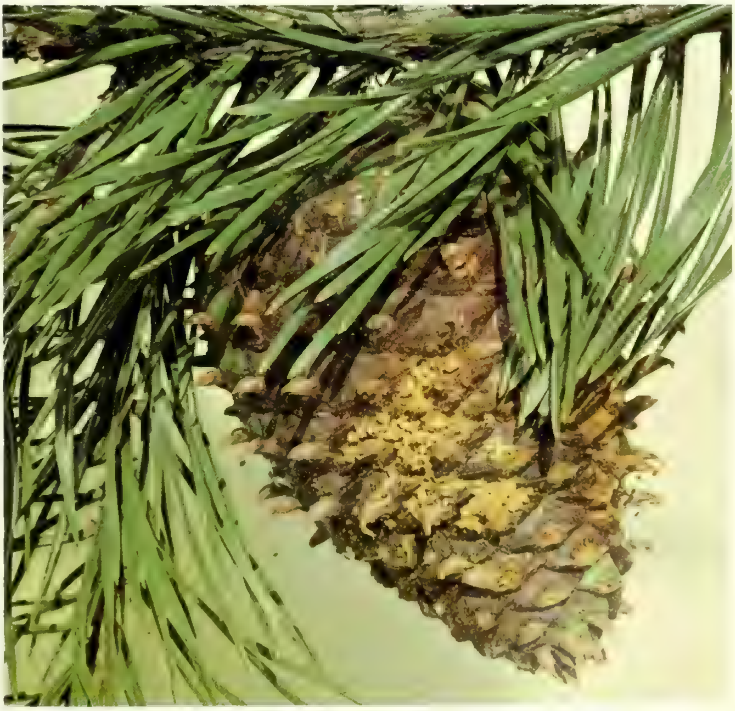
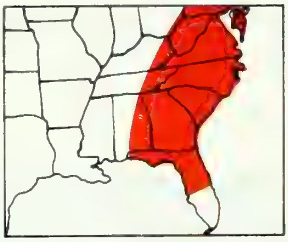


Figure 12f. — Mountain pine coneworm damage to Table-Mountain pine cone. (1X)

Pine Coneborers (*Eucosma* spp.)

Damage is similar to that of *Dioryctria* spp., but the riddled cones tend to be packed with
mixture of chewings and frass with no obvious tunnel system.

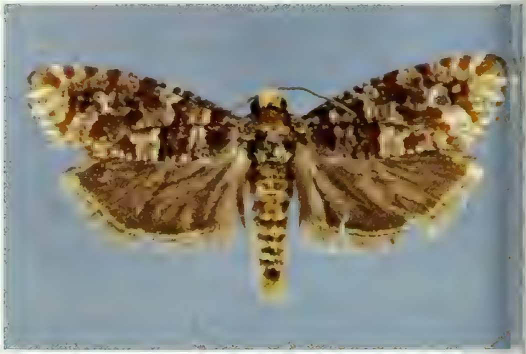
Shortleaf pine coneborer, *Eucosma cocana* Kearfott (6, 24, 26, 27, 42)



BIOLOGY. – The shortleaf pine coneborer has a sing generation each year. Moths emerge from overwintered pupae i the soil and lay small overlapping groups of eggs under th scales of cone stalks in the spring (April-May). Young larva feed in groups in immature cones, then disperse, tending t become more solitary in subsequently infested cones. Dispers tends to be within a major branch system so that infested (d killed) cones within the tree crown are noticeably groupe When mature (June-July), the larvae drop from the cones an pupate in the soil until the following spring.

INSECT IDENTIFICATION (figs. 20g and 21g). – Larvae are light pink-purple with brown heads. Moths are mottled in orange-brown and silver.

Figure 21g. – Shortleaf pine coneborer. (3X)



DAMAGE IDENTIFICATION (fig. 14). – The first cones infested in the spring are usually peppered by small exit holes created by dispersing larvae. Subsequently attacked cones have oval entry-exit holes (2x3 mm) near the cone base together with small holes scattered along the cone surface where larvae break through the cone surface while feeding. Fine chewings and frass can be present on the surface of infested cones. The cone interior is riddled and packed with frass and chewings.

IMPORTANCE. – This insect commonly infests shortleaf pine cones. Extent of damage is comparable to that of coneworms. On loblolly pine it occurs less frequently and is generally of minor importance.

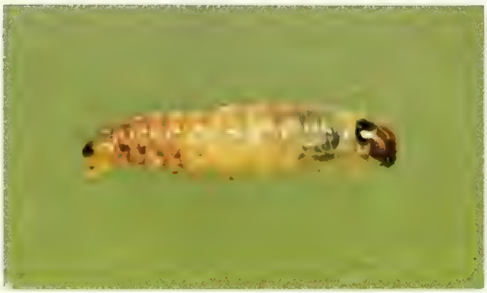


Figure 20g. – Shortleaf pine coneborer. (3X)

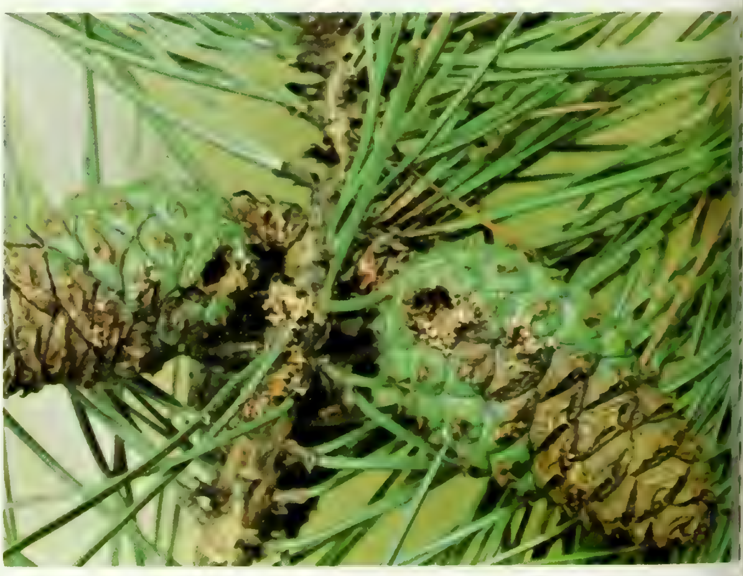
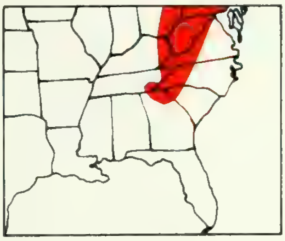


Figure 14. – Shortleaf pine coneborer damage to shortleaf pine cone (1X)

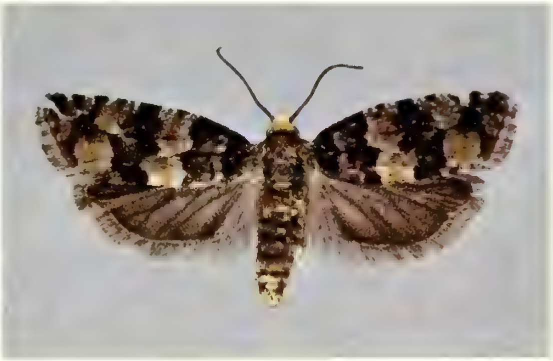
White pine coneborer, *Eucosma tocullionana* Heinrich (1, 39; 42)



BIOLOGY. — Knowledge of the biology of the white pine coneborer is incomplete. The first signs of damage appear in late spring, and pupation and adult emergence occur in middle to late summer. The attack pattern is similar to that of the shortleaf pine coneborer, particularly in cones of Virginia pine.

INSECT IDENTIFICATION (figs. 20h and 21h). — Larvae of the white pine coneborer are similar in size to the shortleaf pine coneborer but are greenish-brown and do not have a distinct dark patch on the top of the last abdominal segment (anal shield) (fig. 19e). The moths have distinct patches of alternating rich brown and light-tan scales on the forewings.

Figure 21h. — White pine coneborer. (3X)



DAMAGE IDENTIFICATION (fig. 15). — Eastern white pine cones are peppered with many small holes and covered with patches of extruded frass. Virginia pine cones attacked by either the white pine coneborer or shortleaf pine coneborer are indistinguishable.

IMPORTANCE. — While relatively limited observations have been made on this insect, its recent destructive occurrence in young seed orchards indicates it has the potential to be a serious pest of eastern white and Virginia pines.

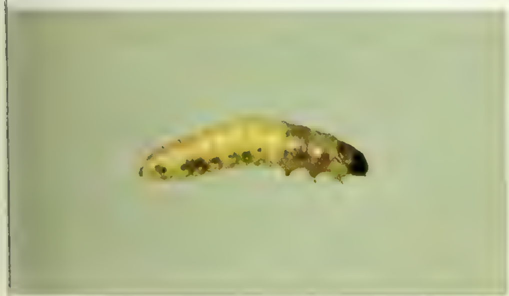


Figure 20h. — White pine coneborer. (2X)

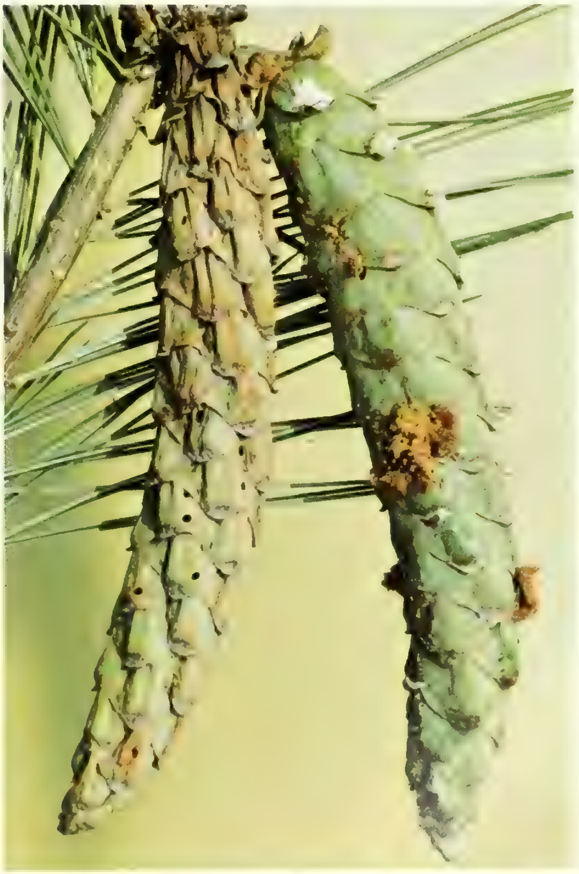
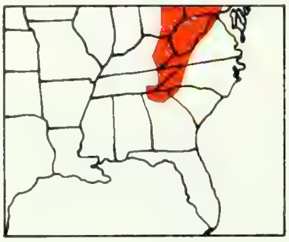


Figure 15. — White pine coneborer damage to eastern white pine cones. (1X)

Pine Cone Beetles (*Conophthorus* spp.)

Members of this genus are the only beetles that attack healthy living cones in the South. T other beetle genera, *Ernobius* and *Pityophthorus*, often implicated in causing pine conelet and c losses, are secondary invaders of dead and dying conelets and cones.

White pine cone beetle, *Conophthorus coniperda* (Schwarz) (1, 39)



BIOLOGY. — Adults emerge in the early spring. Over a per of about 30 days, each female attacks several cones, laying e in some or all of them. The female beetle constructs a gall down the cone axis, laying her eggs in from 1 to 24 nitches into the gallery walls. The larvae feed on both seed and c tissues. When cones are scarce, conelets are attacked but no e are laid in them. There is one generation per year, and the n adults overwinter in the infested cones.

INSECT IDENTIFICATION (fig. 16). — Adult beetles are about 3 to 4 mm long, shiny black, and covered with moderately long erect hairs. The head is directed downward and may not be visible from above. Larvae are creamy white, legless, and somewhat C-shaped.

DAMAGE IDENTIFICATION (fig. 16). — The beetles always attack the base of the cone where it joins the stalk, usually on the underside. The entrance hole is surrounded by a characteristic doughnut-shaped mass of resin-soaked light-brown frass. Attacked cones soon wither and die. Infested cones feel spongy, and the interior tissues are completely destroyed as larvae near the completion of their development.

IMPORTANCE. — In the South, the white pine cone beetle is a serious problem in eastern white pine seed production areas, and its occurrence is increasing in seed orchards. Damage to eastern white pine cone crops in the New England States has been particularly devastating.

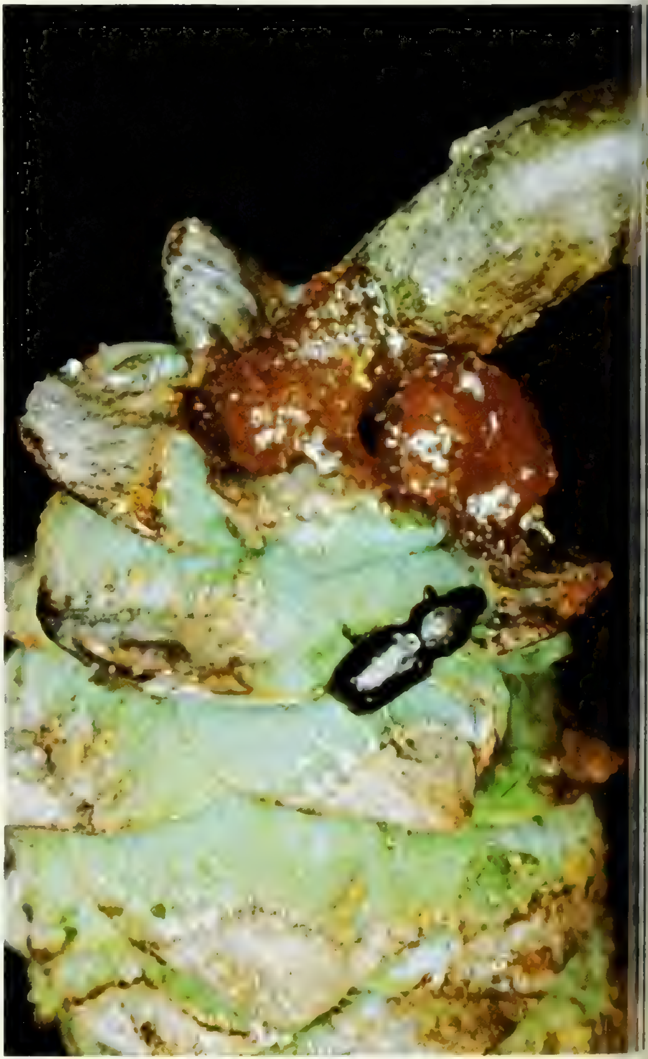
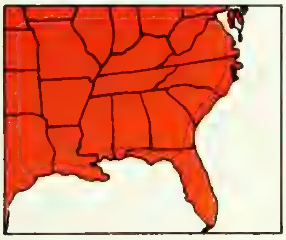


Figure 16. — White pine cone beetle attack of eastern w pine cone. (4X)

ne Feeding Midges, Cecidomyiidae (7, 20, 24, 27)



Several species of midges (small flies) in the family Cecidomyiidae (Diptera) have been identified as cone pests.

BIOLOGY. — Very little information is available on the biology of cone feeding midges attacking the southern pines. Both conelets and cones are attacked, but damage seems to be more common on cones. The larvae feed in groups on both the seed and cone tissues.

SECT IDENTIFICATION (fig.
). — The larvae are 2 to 3 mm
g, tapered, and variable in
or from near white to orange.
ults are very small and mos-
ito-like, with long delicate legs
d antennae (2 mm long). Sev-
l insect genera have been iden-
ed, but the relative impor-
ce of the individual species is
certain.

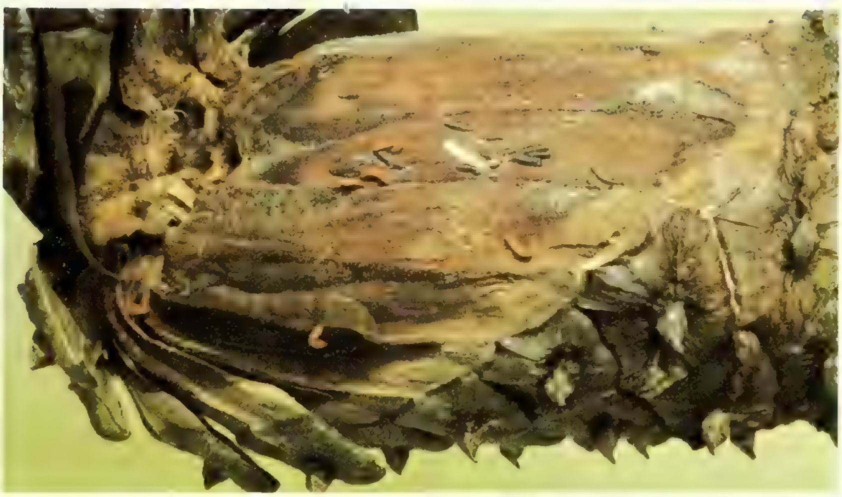


Figure 17. — Pine cone scales removed to expose cone feeding midge larvae and pupae. (2X)

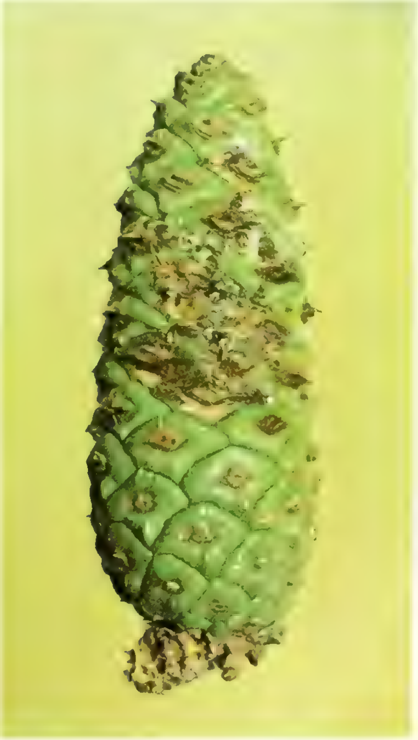


Figure 18. — Loblolly pine cone damaged by cone feeding midges of the family Cecidomyiidae. (1X)

MAGE IDENTIFICATION (figs. 17 and 18). — Cone feeding
dge larvae feed between the cone scales and cause resinosis and
hering of the scales. Internally, infested cones have areas of
d resin-soaked tissue between the scales, which are notably free
any boring frass. Externally, cone feeding midge attack is
icated by brown sunken areas on the cone surface, often
ompanied by some resinosis. This damage often causes distor-
n and decrease in size of cones.

ORTANCE. — Accurate estimates of the impact of cone
ding midges on cone production are not available. Casual
ervations, however, indicate that the incidence of damage is
ally low.

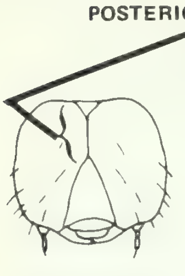


Figure 19a.

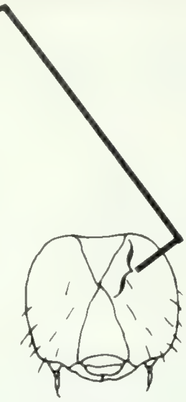


Figure 19b.

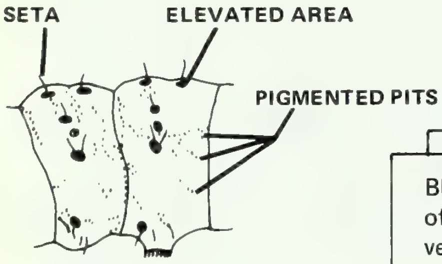


Figure 19c.

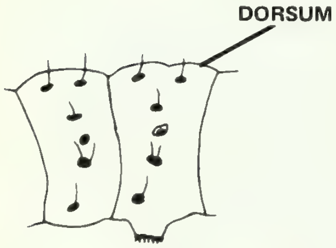


Figure 19d.

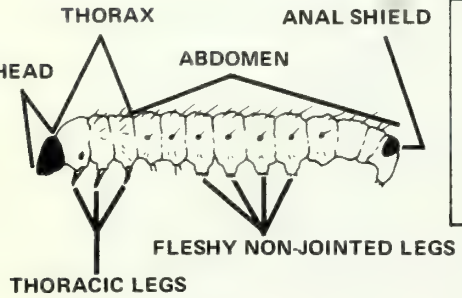


Figure 19e.

KEY TO MATURE CONEBORING CATERPILLARS

- Head with Y-shaped suture as in fig. 19a; beaded patterns of small dark spots (pits) often obvious; larvae usually larger (15 to 33 mm).

  Coneworms
  - Black beadlike pattern of small spots (pits) very obvious (fig. 19c).

    Group I larvae
    - Color of abdomen purplish-brown above; nearly white below often with greenish tints.

      Southern pine coneworm, p. 14
    - Color of abdomen light off-white to purplish-pink above; off-white to pale green below.

      Mountain pine coneworm, p. 21
    - Color of abdomen dark purplish-black above; blue-green below.

      Loblolly pine coneworm, p. 20
  - Beadlike pattern of small spots (pits) less noticeable to indistinct (fig. 19d).

    Group II larvae
    - Color of abdomen ora brown or often tinged v gray above; paler beneath.

      Blister coneworm, p. 15
    - Color of abdomen gray buff above; paler below.

      Webbing coneworm, p. 18
    - Color of abdomen redd purple above; paler bel often with greenish tint.

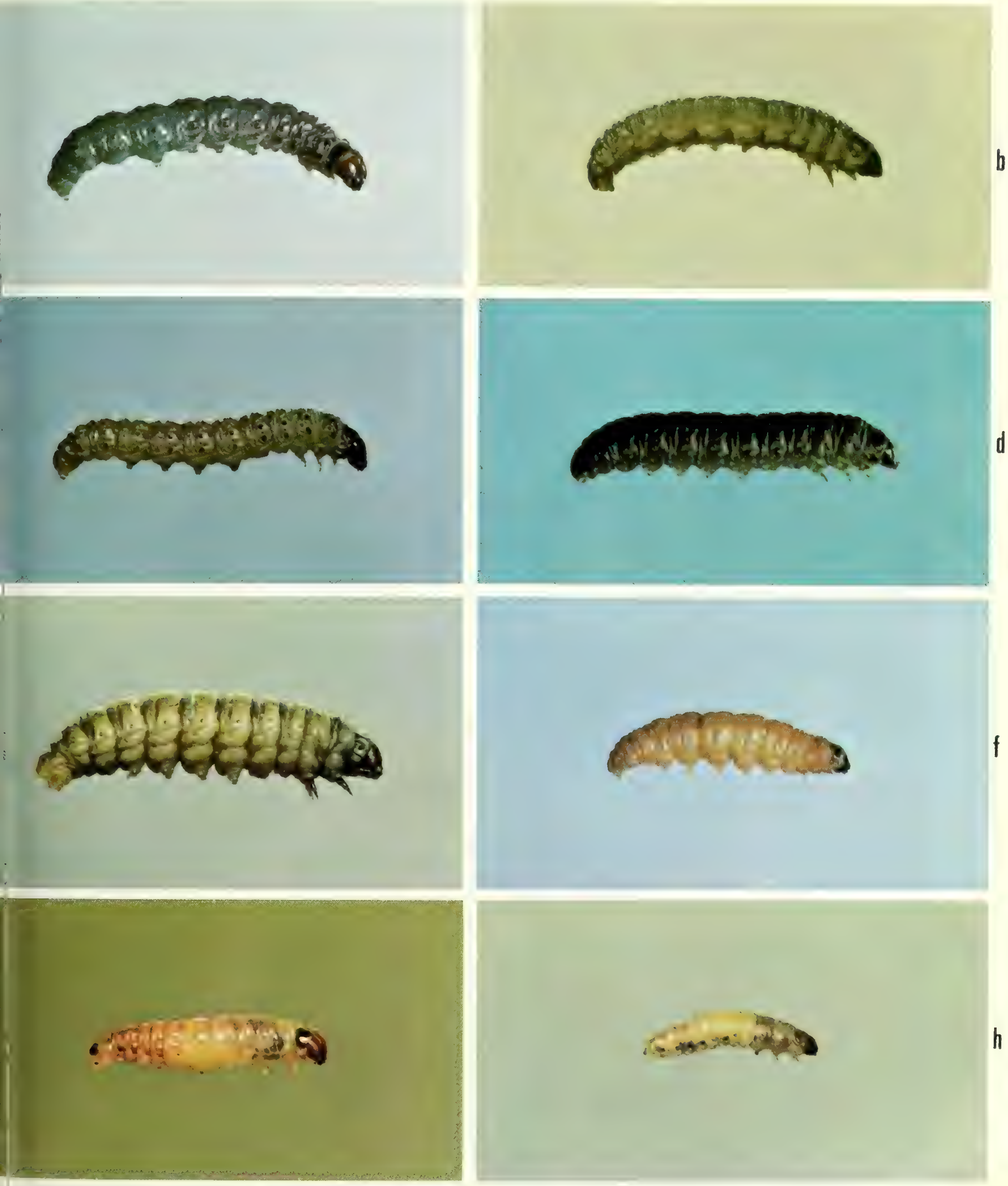
      South coastal coneworm, 19
- Head with V-shaped sutur in fig. 19b; no beaded b patterning; larvae usu smaller (10 to 15 mm).

  Coneborers
  - Prominent dark patch on back of last abdominal segment (anal shield, fig. 19e); body color usually pinkish-purple.

    Shortleaf pine coneborer, p. 22
  - Without dark patch back of last abdom segment (fig. 1 body color gree tan.

    White pine conebo p. 23

Figure 19. — Coneworm and coneborer larvae: (a) dorsal view of coneworm larva head, Y-shaped suture; (b) dorsa view of coneborer larva head, V-shaped suture; (c) lateral view of two abdominal segments of Group 1 conewor larvae; (d) lateral view of two abdominal segments of Group II coneworm larvae; (e) lateral view of generalize larva.



igure 20. — Coneboring caterpillars: (a) southern pine coneworm; (b) south coastal coneworm; (c) mountain pine coneworm; (d) loblolly pine coneworm; (e) webbing coneworm; (f) blister coneworm; (g) shortleaf pine coneborer; (h) white pine coneborer. (2-3X)

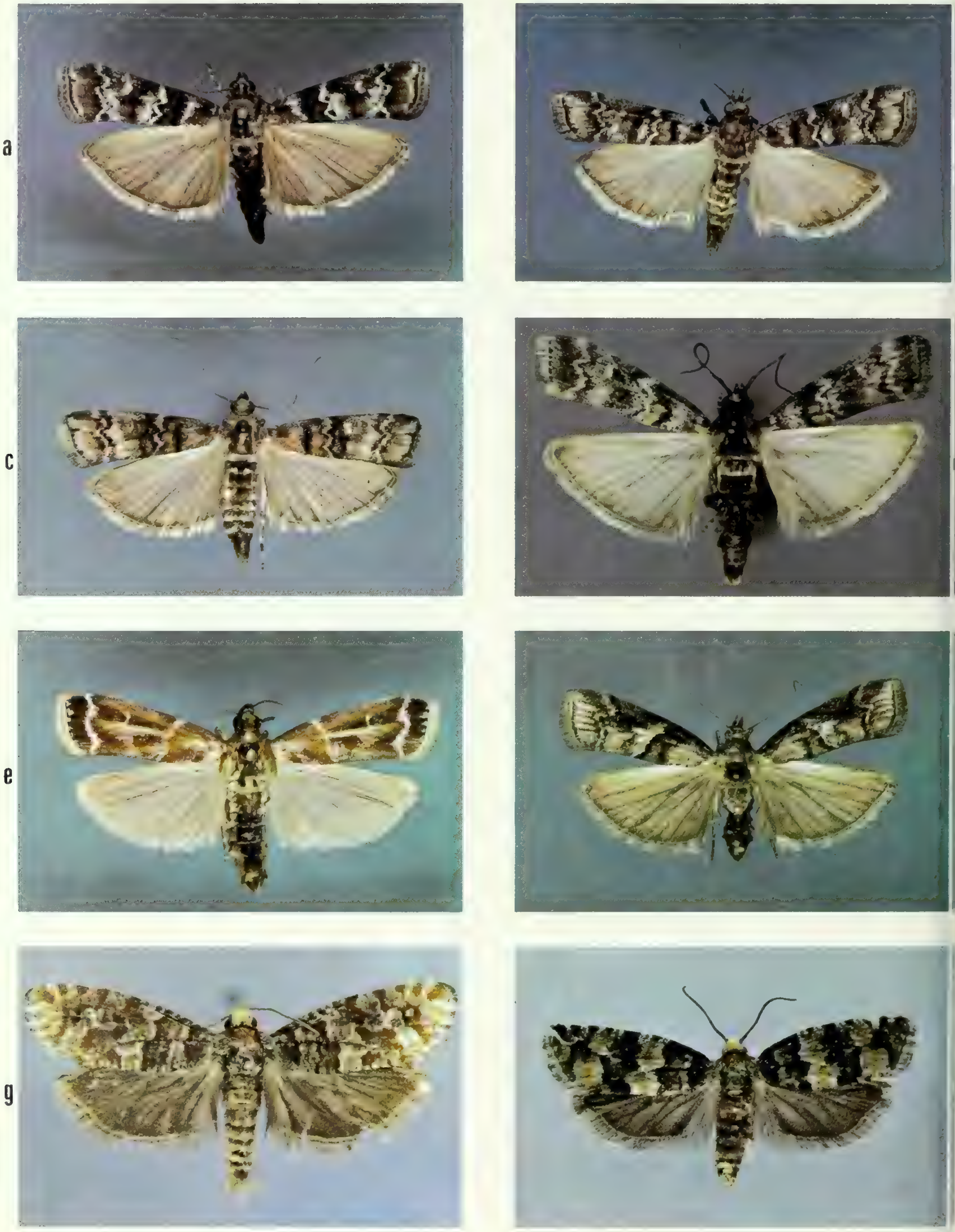


Figure 21. — Coneboring caterpillar adults: (a) southern pine coneworm; (b) mountain pine coneworm; (c) loblol pine coneworm; (d) south coastal coneworm; (e) webbing coneworm; (f) blister coneworm; (g) shortleaf pi coneborer; (h) white pine coneborer. (2-3X)

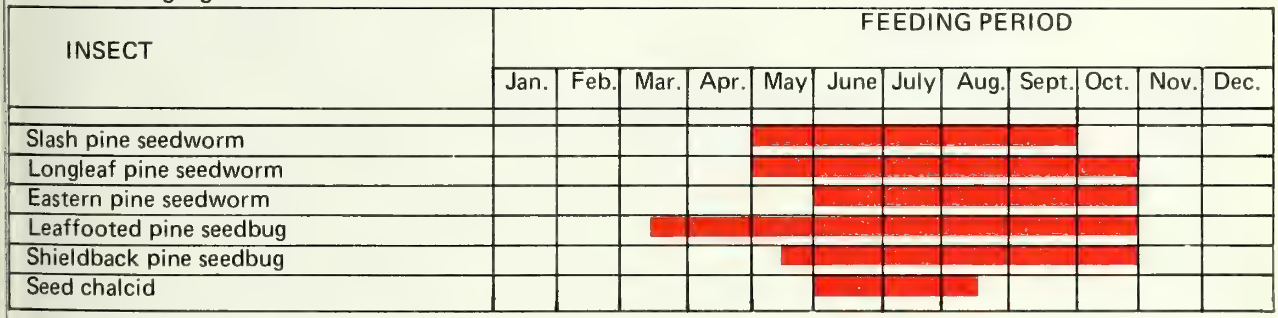
SEED DAMAGE

This group includes insects that feed upon developing seeds in the conelets and cones of pines. Outwardly, cones containing seeds damaged by seedbugs or infested by seed chalcids and seedworms appear healthy, even when extensive internal seed loss has occurred.

Seed Damaging Insects

INSECT	HOST PINES						
	Longleaf	Shortleaf	Loblolly	Slash	Virginia	Eastern White	Table-Mountain
Longleaf pine seedworm	Yes	No	Yes	Yes	No	No	No
Slash pine seedworm	Uncommon	No	Uncommon	Yes	No	No	No
Eastern pine seedworm	No	Yes	Yes	No	Yes	No	No
Leaffooted pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shieldback pine seedbug	Yes	Yes	Yes	Yes	Yes	Yes	?
Seed chalcid	No	No	No	No	No	Yes	No

Seed Damaging Insects



INSECT	FEEDING PERIOD											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Slash pine seedworm					🟥	🟥	🟥	🟥	🟥			
Longleaf pine seedworm					🟥	🟥	🟥	🟥	🟥	🟥		
Eastern pine seedworm						🟥	🟥	🟥	🟥	🟥		
Leaffooted pine seedbug			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥		
Shieldback pine seedbug					🟥	🟥	🟥	🟥	🟥	🟥		
Seed chalcid						🟥	🟥	🟥				

KEY TO RADIOGRAPH OF DAMAGE IN MATURE SEED

- Seed contains damaged tissue or larval frass; larva absent (figs. 22c and 22d).
  - Seed contents partially destroyed (fig. 22c).

    Pine seedbugs, 2 species, p. 33
  - Seed contains frass packed in concentric layers (fig. 22d).

    Pine seedworms, 3 species, p. 31
- Seed contains only larva; eastern white pine only (fig. 22e).

  Seed chalcid, p. 37

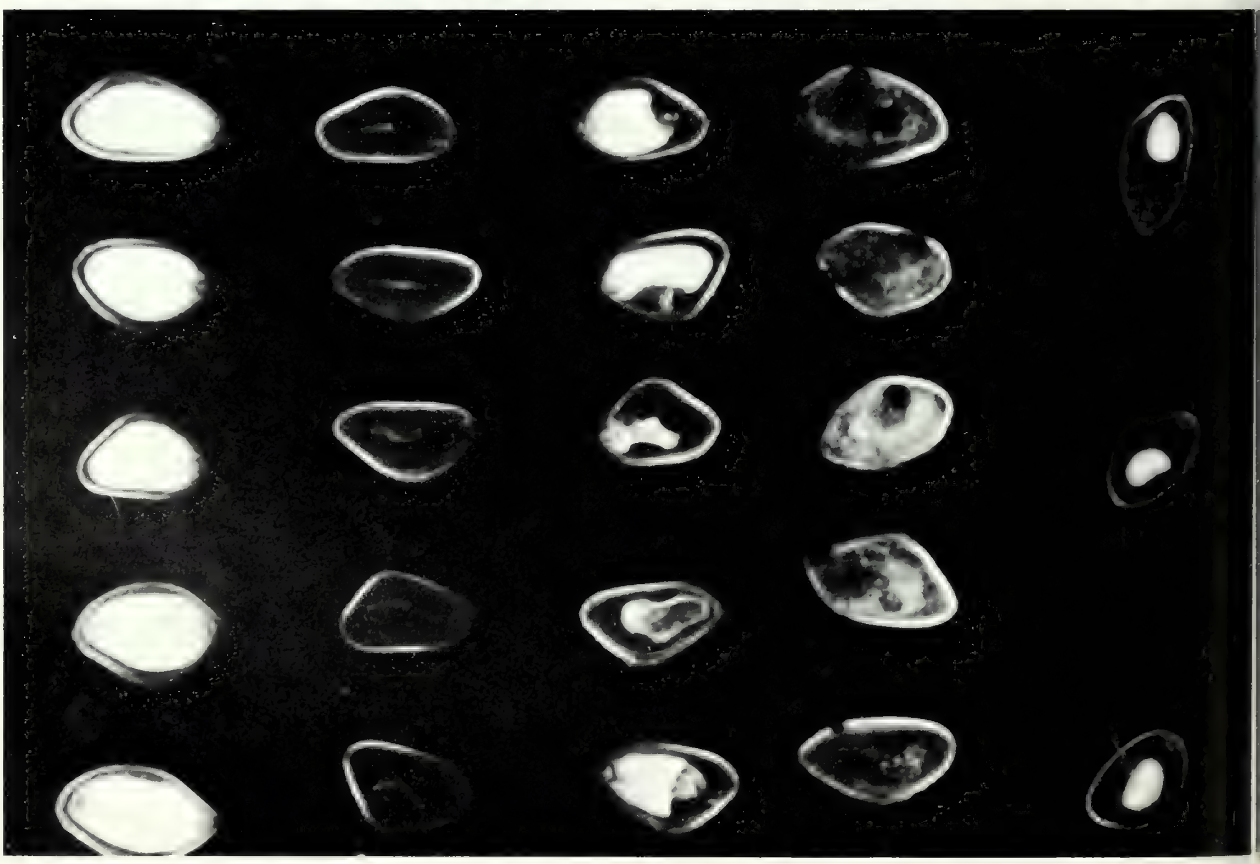
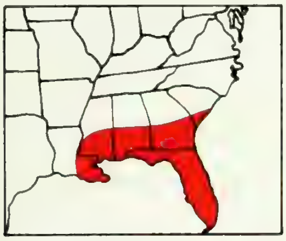
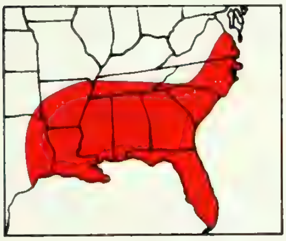


Figure 22. — Radiograph of pine seed: (a) sound seed; (b) empty seed; (c) seedbug-damaged seed; (d) seedworm-damaged seed; (e) seed chalcid-damaged seed. (2X)

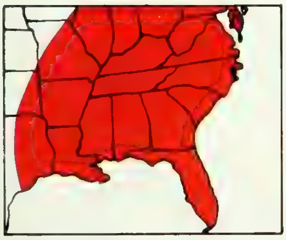
ine Seedworms, *Laspeyresia* spp. (5, 10, 20, 23, 33, 37, 38, 39, 47)



Slash pine seedworm



Longleaf pine seedworm



Eastern pine seedworm

SPECIES. — In the South, three species, the slash pine seedworm, *L. anaranjada* Miller; the longleaf pine seedworm, *L. ingens* Heinrich; and the eastern pine seedworm, *L. toreuta* (Grote), are known to destroy seeds of one or more of the major southern pine species. Damage is caused by larval feeding and development within maturing seeds or cones.

BIOLOGY. — The biology of all three species is similar except for the time of adult occurrence. There is only one generation per year. In the spring the adult moths emerge and mate, and the females lay eggs on the cones. The eggs hatch in 3 to 6 days and the young larvae bore into the cones. Each young larva enters a seed and completely consumes the endosperm. The larva then bores its way to another seed, leaving the excrement-filled, hollowed seed behind. Each larva consumes from five to seven seeds during development. In the fall, the mature larva bores to the cone axis where it overwinters. The following spring the seedworm pupates within its cone gallery. The moth escapes from a hole in a seed held between the cone scales of an open cone.

NSECT IDENTIFICATION (figs. 23, 24a, 24b nd 24c). — Larvae and pupae of the three species f seedworms are not easily separated. The larvae e whitish with yellowish-brown heads. They are bout 1 cm long when mature. The longleaf and stern pine seedworm moths are almost identical. oth species have dark, slate-gray forewings with veral silvery-white crossbars that are typical of e genus. The crossbar of scales on the tip of the rewing of the longleaf pine seedworm parallels d touches the margin of the wingtip. The outer ossbar of scales on the eastern pine seedworm rallels the wingtip margin but does not touch it. oths of the slash pine seedworm can be easily entified by the orange color of the forewings.

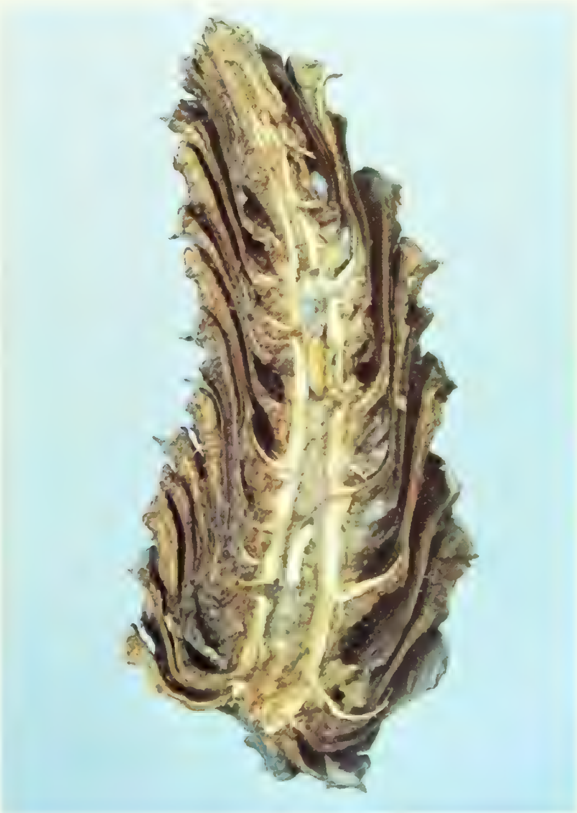


Figure 23. — Pine seedworm larva and pupa in axis of loblolly pine cone. (1X)

(Con't.)

DAMAGE IDENTIFICATION (figs. 22d and 23). — There is no external evidence on cones attacked by seedworms. At cone maturity, most damage seeds remain firmly stuck in the open cones. Damaged seeds are tightly packed with excrement and have larval emergence holes. They are readily identified on a radiograph. The larval galleries in the cone axis can be exposed by bisecting the mature open cone. Counting these galleries is a convenient method of assessing infestation levels.

IMPORTANCE. — Seedworm damage varies considerably among host species. Longleaf pine seed losses up to 40 percent have been recorded. Seedworm damage to seed of other pines is generally minor.

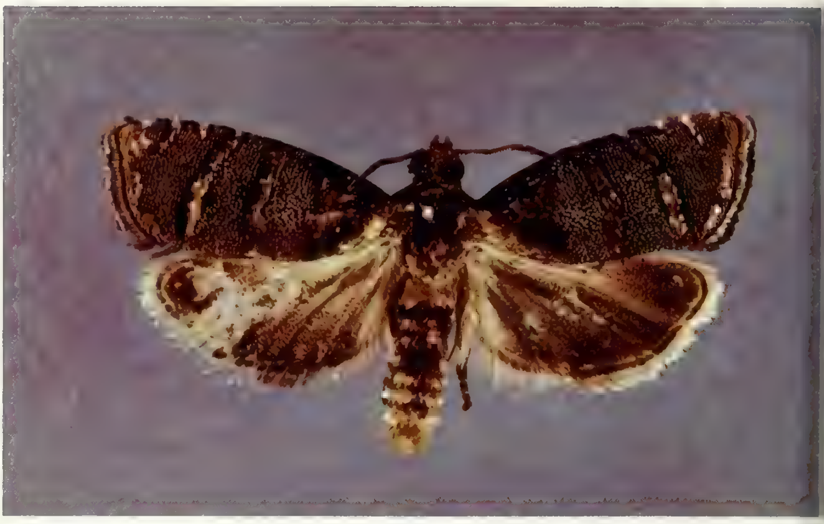


Figure 24a

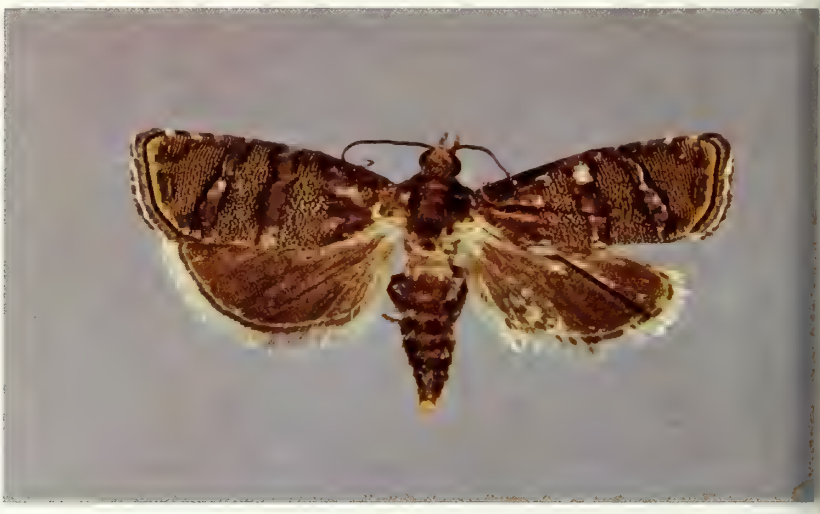


Figure 24b

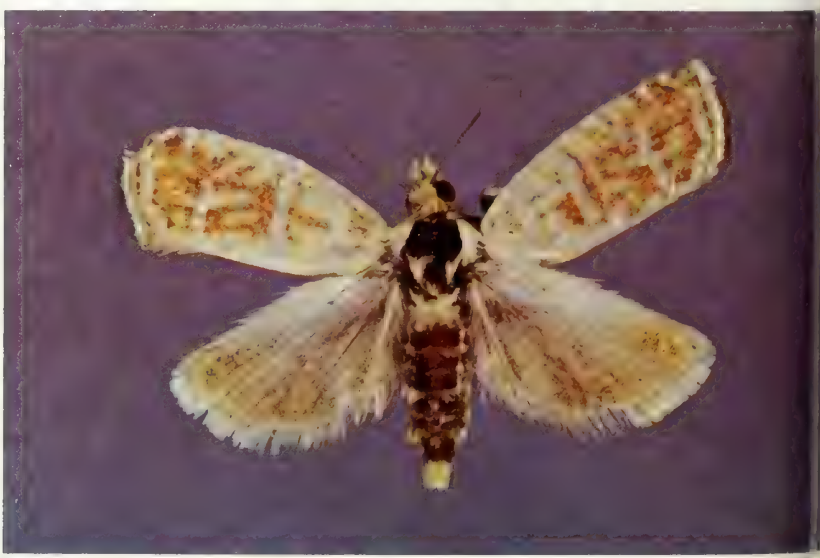


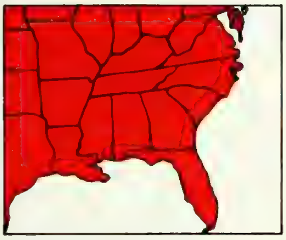
Figure 24c

Figure 24. — Pine seedworm adults: (a) longleaf p seedworm; (b) eastern pine seedworm; (c) sl pine seedworm. (6-7X)

Pine Seedbugs

Seedbugs are sucking insects that feed upon the developing pine cones. Unlike the boring larvae of the more typical cone and seed insects, seedbugs move freely from one cone cluster to another, puncturing through the cone scales with needlelike mouthparts to extract nutrients from individual seeds. Immature bugs are highly mobile within the tree crown, and adult bugs are strong flyers capable of moving throughout the orchard. Early stages are gregarious, and their concentrated feeding may kill conelets or cones. Later stages become solitary feeders. Two species, the leaffooted pine seedbug, *Leptoglossus corculus* (Say), and the shieldback pine seedbug, *Tetyra bipunctata* (H.-S.), commonly occur in seed orchards.

Leaffooted pine seedbug, *Leptoglossus corculus* (Say) (12, 14, 15, 16, 17, 36, 44)



BIOLOGY. — The leaffooted pine seedbug overwinters as an adult. Eggs are laid end to end in neat rows on pine needles. Second-stage nymphs feed on conelets while older nymphs and adults destroy seed in cones. Nymphs are present from April through October, and adults can be found feeding in the spring, summer, and fall. Several generations are produced each year.

NSECT IDENTIFICATION (figs. 25 and 26). — Adults are large, very conspicuous leaffooted bugs about 2 cm long. The most distinctive characterstic of both late-instar nymphs and adults is the eaf-like expansion of the hind legs. Adults are brown with a white zigzag marking across the back. The barrel-shaped eggs are cream colored when aid, turning dark reddish-brown.

Figure 25. — Leaffooted pine seedbug feeding on loblolly pine cone. (3X)

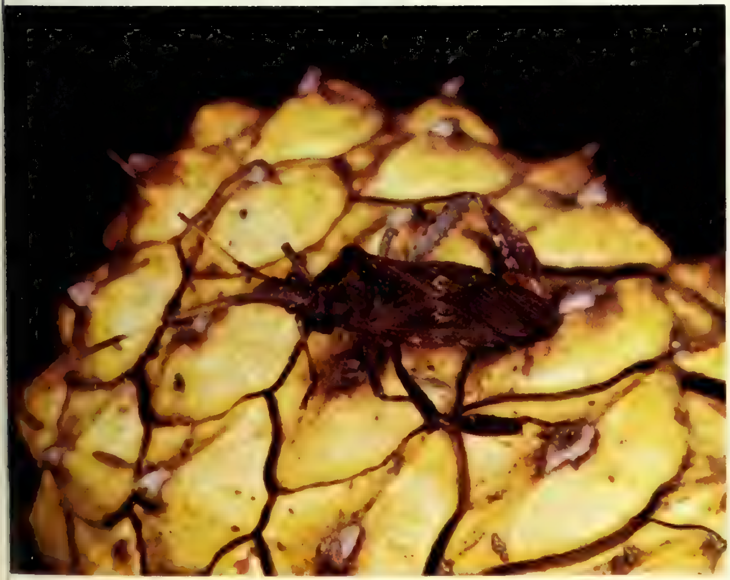
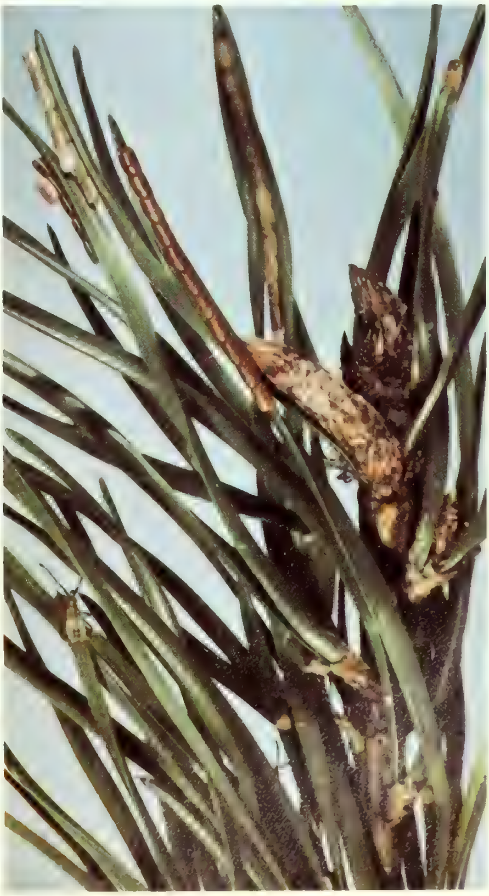


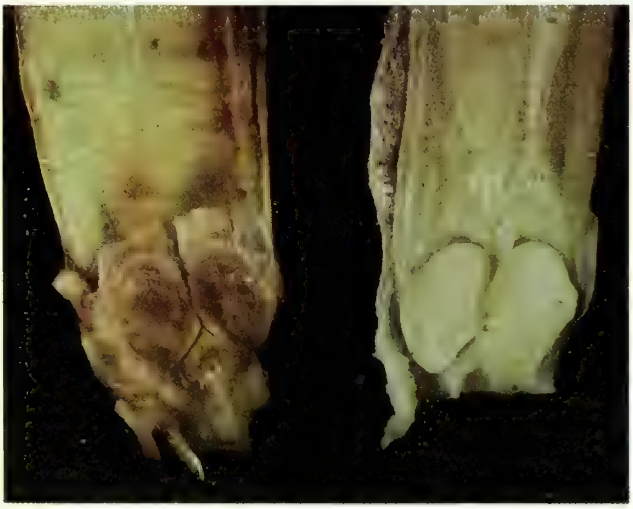
Figure 26. — Egg masses of the leaffooted pine seedbug on shortleaf pine needles; first stage nymph on needle at lower left. (2X)



DAMAGE IDENTIFICATION (figs. 22c, 27, 28, 29 and 30). — Seedbugs feed upon developing see by inserting their mouthparts between conelet scales or by puncturing cone scales, leaving only microscopic vestige of their visit. Aborted conelets (or cones) lacking any obvious signs of injur low yields of seed, high numbers of empty seed, poor seed viability, or mold in germination tests all these conditions may be the result of feeding by the leaffooted pine seedbugs.

Damage to nearly mature seed can often be identified under magnification. Partial digestion o the seedcoat by the insect saliva produces a fleck on the seed and sometimes the minute ho penetrating the seedcoat can be detected. Seeds damaged late in the growing season can often b identified on radiographs of mature seeds. This technique is valuable for comparing seedbug damag among clones or among treatments in insecticide tests, but it usually provides very conservativ estimates of the total impact of the leaffooted pine seedbug on seed production.

Figure 28. — Leaffooted pine seedbug damage (left) to developing seed in immature cone. Undamaged seed on right. (2X)



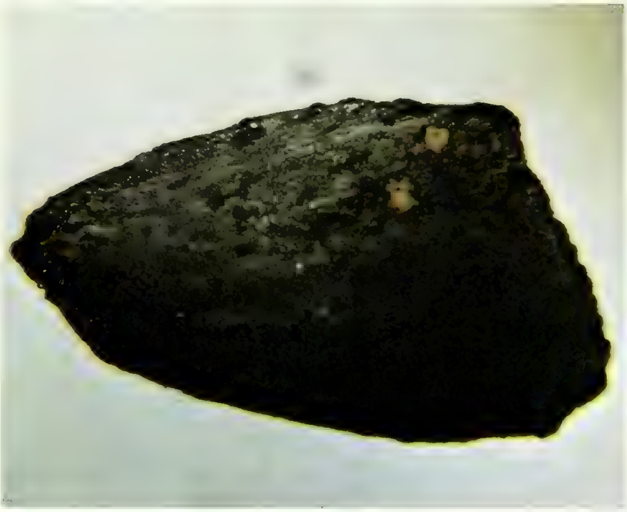
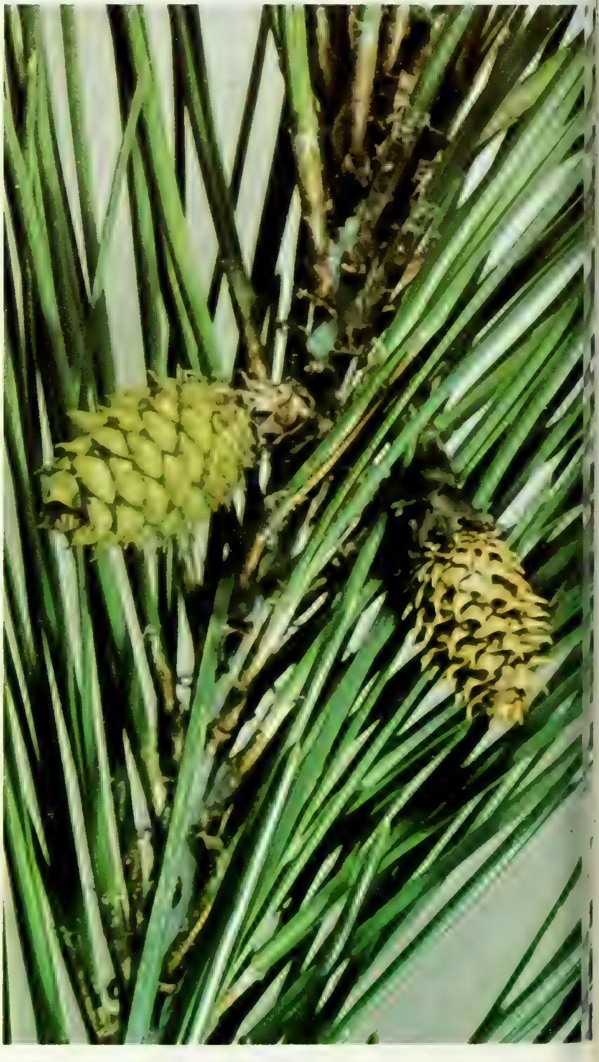


Figure 29. — Slash pine seed with two seedbug feeding holes in seedcoat. (10X)

Figure 27. — Shortleaf pine conelet (right) aborted by leaffooted pine seedbug feeding on immature seed. (1X)



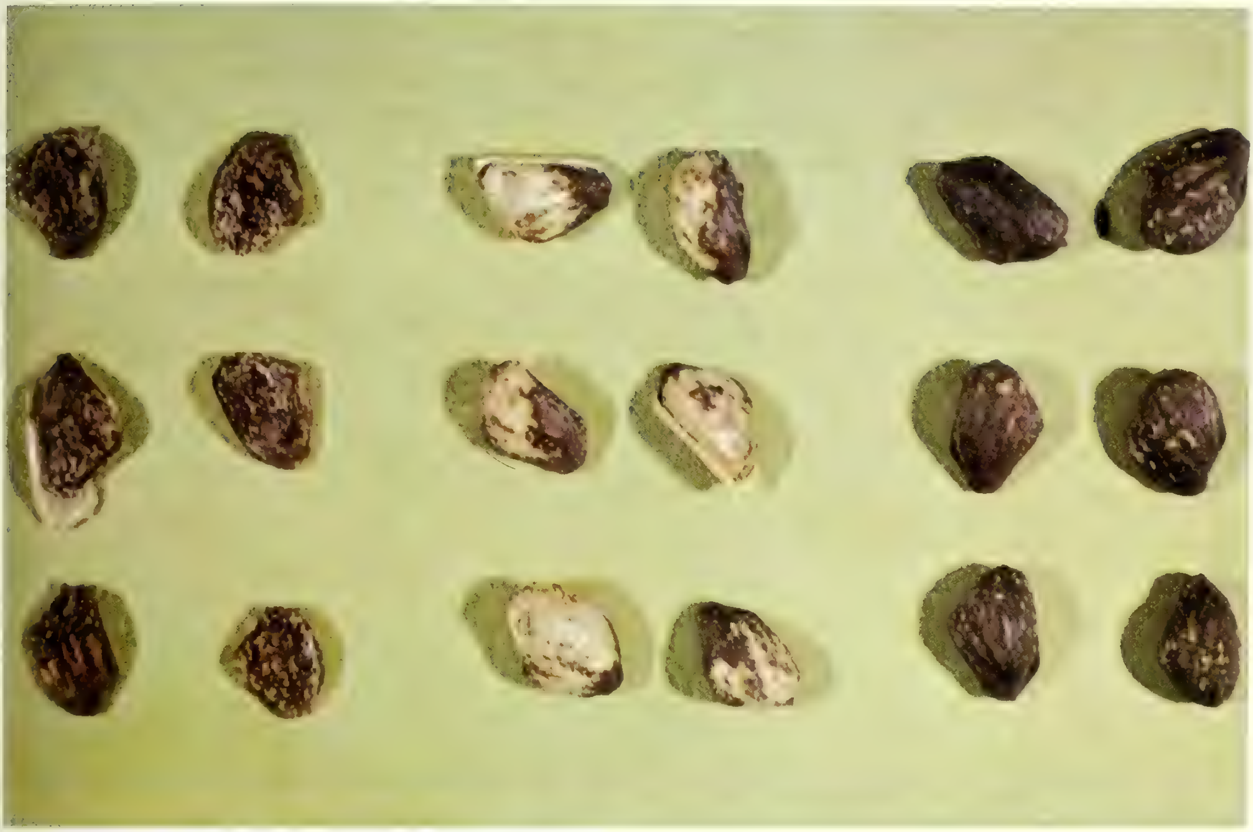
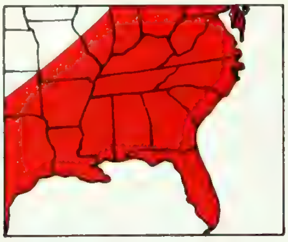


Figure 30. — Effects of seedbug feeding vary with the stage of seed development: seed damage early in the summer are flattened (left); in midsummer damaged seed often have a partially digested seedcoat (center); and seed damaged in the late summer are full size but have internal damage (right). (3X)

IMPORTANCE. — Leaffooted pine seedbugs are of major importance throughout the Eastern United States. All species of pines grown in seed orchards in the South are hosts. Since this seedbug is active throughout the growing season, producing multiple generations each year, relatively few seedbugs per tree cause extensive losses by aborting conelets and destroying immature seeds. Leaffooted pine seedbugs are not readily observed in orchards until cone harvest, but by then losses may have already occurred at earlier stages of seed development. In seed orchards it is not unusual to double the yields of filled seed per cone by protecting conelets and cones with screen-wire cages or insecticides. In some orchards, increases in yields of filled seed per cone as high as tenfold have occurred.

Shieldback pine seedbug, *Tetyra bipunctata* (H.-S.) (12, 14, 15, 16, 28)



BIOLOGY. — The shieldback pine seedbug overwinters as an adult in the litter. Eggs (8 to 14) are laid in two alternate rows on living pine needles or in a random group on a single cone scale. Older nymphs and adults feed primarily on seed within cones. In the Lake States, the shieldback pine seedbug has only one generation per year. This is also apparently true in the South, where overwintered adults are not observed feeding in seed orchards until early summer.

INSECT IDENTIFICATION (figs. 31 and 32). — Adults and nymphs have a shieldlike "stinkbug" shape. Their color varies from gray in the early stages to dark, reddish-brown with black markings as adults. Adults are about 1.5 cm long. The eggs are small, bright green spheres about 1.5 mm in diameter.

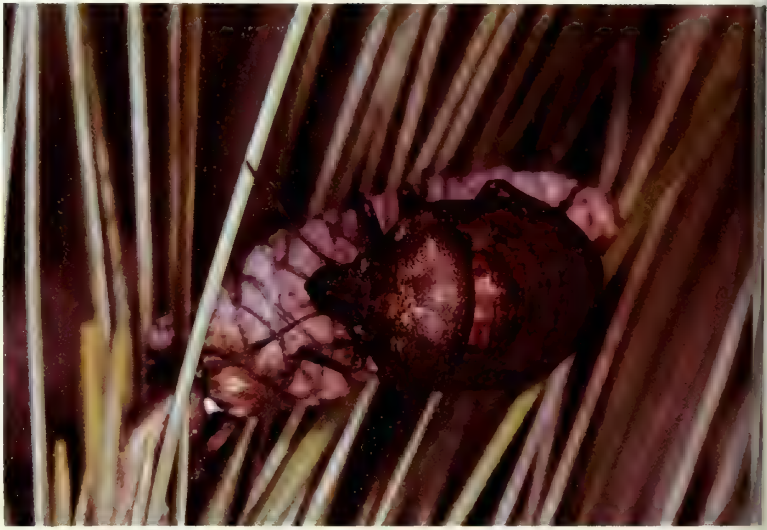


Figure 31. — Shieldback pine seedbug. (3X)

DAMAGE IDENTIFICATION (fig. 30 right). — Feeding by the nymphs and adults of the shieldback pine seedbug is limited to nearly mature seed. Much of this seed damage can be detected by examining mature seeds. These damaged seeds cannot be distinguished either ocularly or radiographically from seeds damaged late in the growing season by the leaffooted pine seedbug.

IMPORTANCE. — The shieldback pine seedbug is found throughout the South, and its hosts include all the major pine species. Peak populations of this seedbug coincide with cone harvest, when the bugs are most frequently observed in seed orchards. Since this insect has only one generation each year and feeding is limited to nearly mature seed, the damage potential of the shieldback pine seedbug is not nearly as great as that of the leaffooted pine seedbug.

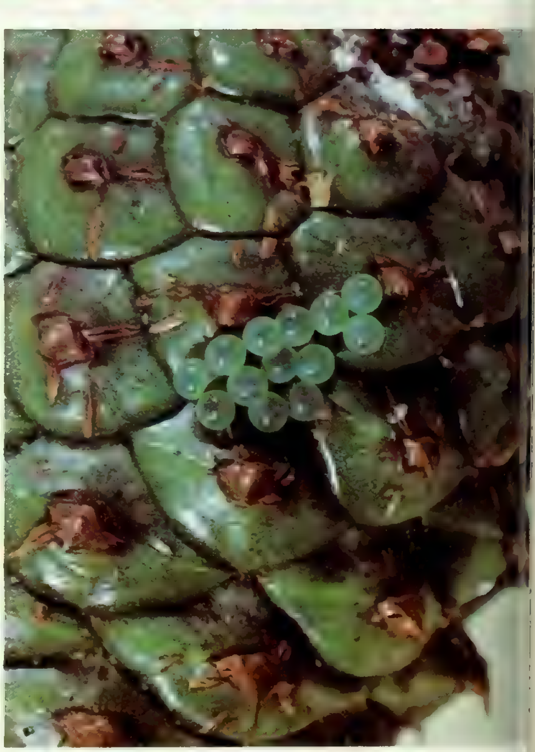
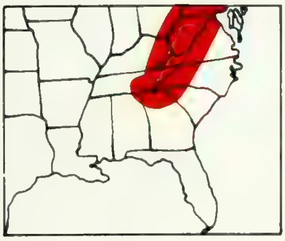


Figure 32. — Egg mass of the shieldback pine seedbug on loblolly pine cone. (3X)

Seed Chalcid, *Megastigmus atedius* **(Walker) (1, 11, 45)**

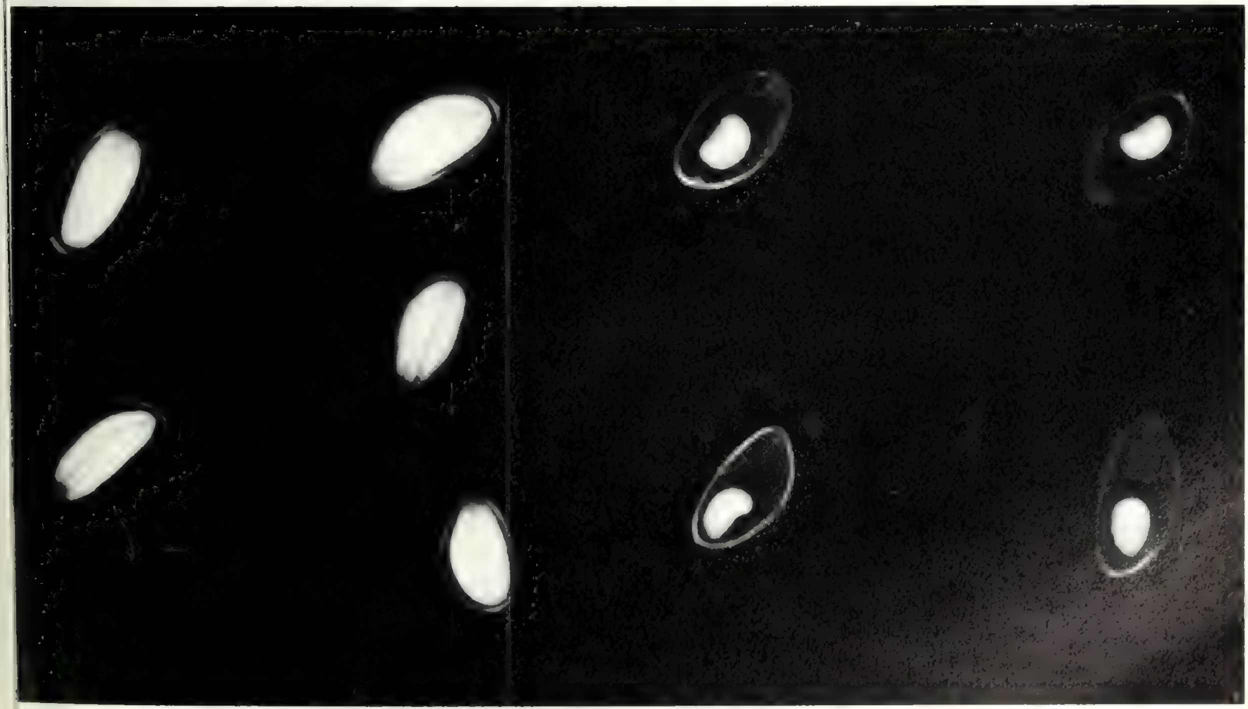


BIOLOGY. — During late spring the female seed chalcid wasp settles on immature cones and inserts her long ovipositor down through the cone scales, depositing eggs directly into the seeds. Each larva feeds for 6 to 8 weeks, consuming the entire contents of a seed. Larvae overwinter in the seed; pupation and adult emergence occur in the spring. Some larvae, however, may remain in a resting condition for up to 3 years. The adult wasp emerges in late May through a hole it bores in the seedcoat.

INSECT IDENTIFICATION. — Adult seed chalcid wasps are only about 3 mm long and are seldom seen. Larvae are white and legless with dark brown to black mandibles.

DAMAGE IDENTIFICATION (fig. 22e). — Infested seeds cannot be distinguished from sound seeds except by dissection or radiography.

IMPORTANCE. — Seed chalcid damage to eastern white pine is believed to be rare, as reports of damage have been infrequent.



igure 33. — Radiograph of eastern white pine seed: five seeds on left, normal; four seeds on right, infested with the seed chalcid. (3X)

GLOSSARY

ABDOMINAL SEGMENT – a subdivision of the abdomen of a larva delineated by constrictions; no more than one pair of legs per segment.

ANAL SHIELD – a pigmented hard area on the back of last abdominal segment of a larva.

CONE – the female strobilus of pines from the time of appearance of a new conelet crop to maturity (second growing season).

EPIDEMIC – a state of high population of an insect species.

FLOWER – the exposed male and female reproductive structure before or during pollination.

FLOWER BUD – buds which contain either male or female strobili tissues.

FRASS – solid excrement of insects.

RESIN (oleoresin) – sticky substance which exudes from injured pine tissues.

RESINOSIS – plant lesions or surrounding areas infused with resin.

SETA (pl. setae) – slender hair-like structure on insect body; a bristle.

STROBILUS – the reproductive structure of conifers.

Scientific Names of Hosts

Eastern white pine	-	*Pinus strobus* L.
Loblolly pine	-	*Pinus taeda* L.
Longleaf pine	-	*Pinus palustris* Mill.
Pitch pine	-	*Pinus rigida* Mill.
Sand pine	-	*Pinus clausa* (Chapm.) Vasey
Shortleaf pine	-	*Pinus echinata* Mill.
Slash pine	-	*Pinus elliottii* Engelm. var. *elliottii*
Spruce pine	-	*Pinus glabra* Walt.
Table-Mountain pine	-	*Pinus pungens* Lamb.
Virginia pine	-	*Pinus virginiana* Mill.

Selected References

1. Baker, W. L.
   1972. Eastern forest insects. USDA For. Serv. Misc. Publ. 1175, 642 p.
2. Beal, R. H.
   1958. Life habits and control of pine tip moth: results from preliminary studies. USDA For. Serv. South. For. Pest Rep. 24, 5 p. South. For. Exp. Stn., New Orleans, La.
3. Bramlett, D. L., and J. G. Hutchinson.
   1965. Pine sawfly larvae destroy shortleaf pine strobili in Virginia. U.S. For. Serv. Res. Note SE-42, 3 p. Southeast. For. Exp. Stn., Asheville, N.C.
4. Burdick, D. J.
   1961. A taxonomic and biological study of the genus *Xyela* Dalman in North America. Univ. Calif. Publ. Entomol. 17: 285-356.
5. Ciesla, W. M., and J. C. Bell, Jr.
   1966. A new host record for the seedworm, *Laspeyresia toreuta,* with notes on its biology. J. Econ. Entomol. 59: 1025-1026.
6. Ciesla, W. M., J. L. Rauschenberger, and J. C. Bell, Jr.
   1968. *Eucosma* infestations in shortleaf pine cones. J. Econ. Entomol. 61: 1129-1130.
7. Coulson, R. N., and R. T. Franklin.
   1968. Frequency of occurrence of cone- and seed-destroying insects on shortleaf pine in the Georgia Piedmont. J. Econ. Entomol. 61: 1026-1027.
8. Coulson, R. N., and R. T. Franklin.
   1970. The biology of *Dioryctria amatella* (Lepidoptera: Phycitidae). Can. Entomol. 102: 679-684.
9. Coulson, R. N., A. Mutuura, and E. Munroe.
   1972. The *Dioryctria* species of loblolly pine in east Texas, with comments on the occurrence of two new species. J. Econ. Entomol. 65: 868-870.
10. Coyne, J. F.
    1968. *Laspeyresia ingens,* a seedworm infesting cones of longleaf pine. Ann. Entomol. Soc. Am. 61: 1116-1122.
11. Craighead, F. C.
    1950. Insect enemies of eastern forests. U.S. Dept. Agric. Misc. Publ. 657, 679 p.
12. DeBarr, G. L.
    1967. Two new sucking insect pests of seed in southern pine seed orchards. U.S. For. Serv. Res. Note SE-78, 3 p. Southeast. For. Exp. Stn., Asheville, N.C.
13. DeBarr, G. L.
    1969. The damage potential of a flower thrips in slash pine seed orchards. J. For. 67: 326-327.
14. DeBarr, G. L.
    1970. Characteristics and radiographic detection of seedbug damage to slash pine seed. Fla. Entomol. 53: 109-117.
15. DeBarr, G. L.
    1974. Quantifying the impact of seedbugs, p. 34-41. *In* John Kraus (ed.), Seed yield from southern pine seed orchards colloquium proceedings. Ga. For. Res. Counc., Macon, Ga.
16. DeBarr, G. L., and B. H. Ebel.
    1973. How seedbugs reduce the quantity and quality of pine seed yields. Twelfth South. For. Tree Improv. Conf. Proc. 1973: 97-103.
17. Debarr, G. L., and B. H. Ebel.
    1974. Conelet abortion and seed damage of shortleaf and loblolly pines by a seedbug, *Leptoglossus corculus.* For. Sci. 20: 165-170.
18. DeBarr, G. L., and J. A. Williams.
    1971. Nonlethal thrips damage to slash pine flowers reduces seed yields. USDA For. Serv. Res. Note SE-160, 4 p. Southeast. For. Exp. Stn., Asheville, N.C.
19. Ebel, B. H.
    1961. Thrips injure slash pine female flowers. J. For. 59: 374-375.
20. Ebel, B. H.
    1963. Insects affecting seed production of slash and longleaf pines — their identification and biological annotation. U.S. For. Serv. Res. Pap. SE-6, 24 p. Southeast. For. Exp. Stn., Asheville, N.C.
21. Ebel, B. H.
    1965. The *Dioryctria* coneworms of north Florida pines (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Am. 58: 623-630.
22. Ebel, B. H.
    1966. Rearing and occurrence of xyelid sawflies on slash and longleaf pines in north Florida (Hymenopters: Xyelidae). Ann. Entomol. Soc. Am. 59: 227-229.
23. Ebel, B. H.
    1971. Distribution and incidence of *Laspeyresia,* spp. seedworm infestation in Virginia, loblolly and shortleaf pine cones in the southern states. Eleventh South. For. Tree Improv. Conf. Proc. 1971: 95-97.
24. Ebel, B. H.
    1974. Cone and seed insects of shortleaf and loblolly pines in the Georgia Piedmont, p. 26-33. *In* John Kraus (ed.), Seed yield from southern pine seed orchards colloquium proceedings. Ga. For. Res. Counc., Macon, Ga.
25. Ebel, B. H., and G. L. DeBarr.
    1973. Injury to female strobili of shortleaf and loblolly pines by *Nepytia semiclusaria* (Lepidoptera: Geometridae). Fla. Entomol. 56: 53-55.
26. Ebel, B. H., and H. O. Yates III.
    1973. Rearing and biological observations on a southern pine cone insect, *Eucosma cocana* Kearfott (Lepidoptera: Olethreutidae). Ann. Entomol. Soc. Am. 66: 88-92.

Selected References

27. Ebel, B. H., and H. O. Yates III.
    1974. Insect-caused damage and mortality to conelets, cones, and seed of shortleaf pine. J. Econ. Entomol. 67 222-226.
28. Gilbert, B. L., S. J. Barras, and D. M. Norris.
    1967. Bionomics of *Tetyra bipunctata* (Hemiptera: Pentatomidae: Scutellerinae) as associated with *Pinus banksiana* i Wisconsin. Ann. Entomol. Soc. Am. 60: 698-701.
29. Goolsby, R. P., J. L. Ruehle, and H. O. Yates III.
    1972. Insects and diseases of seed orchards in the South. Ga. For. Res. Counc. Rep. 28, 25 p., Macon, Ga.
30. Greenbaum, H. N.
    1974. A new *Xyela* (Hymenoptera: Xyelidae) from Florida. Fla. Entomol. 57: 104-106.
31. Hedlin, A. F.
    1974. Cone and seed insects of British Columbia. Dep. Environ., Can. For. Serv. Publ. BC-X90, 63 p.
32. Heinrich, C.
    1956. American moths of the subfamily Phycitidae. U.S. Nat. Mus. Bull. 207, 581 p.
33. Kraft, K. J.
    1968. Ecology of the cone moth, *Laspeyresia toreuta,* in *Pinus banksiana* stands. Ann. Entomol. Soc. Am. 6 1462-1465.
34. Lyons, L. A.
    1957. Insects affecting seed production in red pine. II. *Dioryctria disclusa* Heinrich, *D. abietella* (D. and S.) and *cambiicola* (Dyar) (Lepidoptera: Phycitidae). Can. Entomol. 89: 70-79.
35. McLemore, B. F.
    1973. Loblolly pine flowers damaged by *Phyllophaga* beetles. J. Econ. Entomol. 66: 541-542.
36. Mead, F. W.
    1971. Annotated key to leaffooted bugs, *Leptoglossus* spp., in Florida (Hemiptera: Coreidae). Fla. Dep. Agri Consum. Serv., Div. Plant Ind. Entomol. Circ. 113, 4 p.
37. Merkel, E. P.
    1963. Distribution of the pine seedworm, *Laspeyresia anaranjada,* with notes on the occurrence of *Laspeyresia ingen* Ann. Entomol. Soc. Am. 56: 667-669.
38. Merkel. E. P.
    1967. Life history of the slash pine seedworm, *Laspeyresia anaranjada* Miller (Lepidoptera: Olethreutidae). F Entomol. 50: 141-149.
39. Morris, C. L., and W. J. Schroeder.
    1967. Pine cone mortality. Va. For. 21(4): 18-19.
40. Neunzig, H. H., E. D. Cashatt, and G. A. Matuza.
    1964. Observations on the biology of four species of *Dioryctria* in North Carolina (Lepidoptera: Phycitidae). Ar Entomol. Soc. Am. 57: 317-321.
41. Neunzig, H. H., R. L. Rabb, B. H. Ebel, and E. P. Merkel.
    1964. Larvae of the genus *Dioryctria* (Lepidoptera: Phycitidae) in the Southeastern United States. Ann. Entomol. S Am. 57: 693-700.
42. Powell, J. A.
    1968. Host associations and taxonomy of Nearctic conifer cone moths in the genus *Eucosma* (Lepidopte Tortricidae). Hilgardia 39: 1-36.
43. Rose, A. H., and O. H. Lindquist.
    1973. Insects of eastern pines. Can. For. Serv. Publ. 1313, 127 p.
44. Rowan, S. J., and G. L. DeBarr.
    1974. Moldy seed and poor germination associated with seedbug damage to slash pine seed lots. USDA For. Serv. T Plant. Notes 25(1): 25-27.
45. Speers, C. F.
    1974. Pine seed chalcid transcontinental in range. USDA For. Serv. Tree Plant. Notes 25(2): 24.
46. Yates, H. O. III.
    1960. The Nantucket pine moth – a literature review. USDA For. Serv. Southeast. For. Exp. Stn. Pap. 115, 19 Asheville, N.C.
47. Yates, H. O. III, and B. H. Ebel.
    1970. Light trap collections of *Laspeyresia ingens* and *L. toreuta* in Clarke County, Georgia (Lepidopte Olethreutidae). J. Ga. Entomol. Soc. 5: 242-247.
48. Yates, H. O. III, and B. H. Ebel.
    1972a. Light-trap collections and review of biologies of two species of pine-feeding Geometridae. J. Ga. Entomol. S 7: 265-271.
49. Yates, H. O. III, and B. H. Ebel.
    1972b. Shortleaf pine conelet loss caused by the Nantucket pine tip moth, *Rhyacionia frustrana* (Comsto (Lepidoptera: Olethreutidae). Ann. Entomol. Soc. Am. 65: 100-104.
50. Yates, H. O. III, and B. H. Ebel.
    1975. Light-trapping and identifying *Dioryctria* that damage pine cones in northeastern Georgia (Lepidopt Phycitidae). J. Ga. Entomol. Soc. 10: 78-86.
51. Yearian, W. C., and L. O. Warren.
    1964. Insects of pine cones in Arkansas. J. Kansas Entomol. Soc. 37: 259-264.

INSECT ATTACK PERIODS

Flower and Conelet Damaging Insects - p. 4

INSECT	FEEDING PERIOD											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Nantucket pine tip moth				🟥	🟥	🟥						
Slash pine flower thrips	🟥	🟥										
Pine conelet looper		🟥	🟥	🟥	🟥	🟥						
Virginia pine sawfly				🟥	🟥	🟥						
May beetles			🟥	🟥								
Pine catkin sawflies	🟥	🟥	🟥	🟥	🟥							
Leaffooted pine seedbug				🟥	🟥	🟥	🟥	🟥	🟥	🟥		
Cone feeding midges		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥		
South coastal coneworm			🟥	🟥	🟥	🟥						
Loblolly pine coneworm		🟥	🟥	🟥	🟥							
Southern pine coneworm		🟥	🟥	🟥								
Blister coneworm		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥		

Cone Damaging Insects - p. 12

INSECT	FEEDING PERIOD											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Southern pine coneworm					🟥	🟥	🟥	🟥	🟥	🟥	🟥	
Blister coneworm		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	
Webbing coneworm				🟥	🟥	🟥						
South coastal coneworm						🟥	🟥	🟥	🟥			
Loblolly pine coneworm					🟥	🟥	🟥					
Mountain pine coneworm							🟥	🟥	🟥			
Shortleaf pine coneborer					🟥	🟥	🟥					
White pine coneborer							🟥	🟥				
White pine cone beetle					🟥	🟥	🟥	🟥	🟥			
Cone feeding midges				🟥	🟥	🟥	🟥	🟥	🟥	🟥		

Seed Damaging Insects - p. 29

INSECT	FEEDING PERIOD											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Slash pine seedworm					🟥	🟥	🟥	🟥	🟥			
Longleaf pine seedworm					🟥	🟥	🟥	🟥	🟥	🟥		
Eastern pine seedworm						🟥	🟥	🟥	🟥	🟥		
Leaffooted pine seedbug			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥		
Shieldback pine seedbug					🟥	🟥	🟥	🟥	🟥	🟥		
Seed chalcid						🟥	🟥	🟥				

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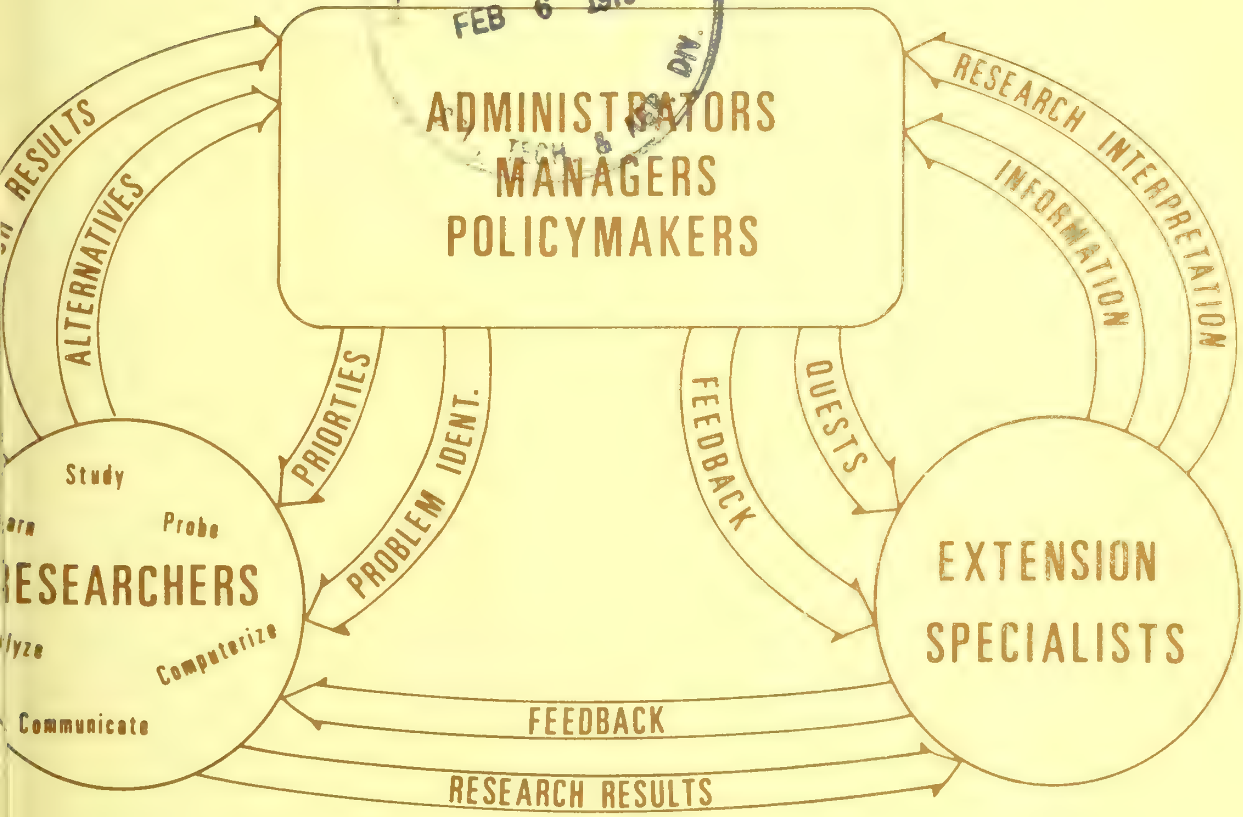

PROCEEDINGS

of the

SOUTHERN STATES RECREATION RESEARCH

Applications Workshop
Asheville, North Carolina
September 15-18, 1975

Proceedings
# of the
Southern States Recreation Research

Southeastern Forest Experiment Station
Forest Service, U.S. Department of Agriculture
Asheville, N.C. 28802

North Carolina State University
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FOREWORD

North Carolina State University; the Forest Environment Research Division, USDA Forest Service; and the Southeastern Forest Experiment Station, USDA Forest Service sponsored this regional Workshop for recreation managers and planners in the Southern States. The objectives of the Workshop were to provide for interaction among recreation scientists, extension specialists, and managers and planners and to exchange ideas and attitudes concerning the usefulness and applicability of the knowledge which has been generated through recreation research. A special emphasis was placed on the effectiveness with which researchers communicate their results to managers and planners and with which research needs are communicated to researchers.

Attendance at the Workshop was limited to 80 specifically invited recreation resource managers, planners, researchers and extension specialists. Invitations were extended to those who had demonstrated interest and accomplishment in the field. Active participation by these invitees in discussions was strongly urged and the Workshop format was designed to encourage maximum participation.

Attendees at the Workshop included personnel from:

- State recreation and/or planning agencies
- State game and fish agencies
- Private forest industries and private recreation enterprises
- Federal agencies including USFS, BOR, SCS, TVA, and the Corps of Engineers
- Recreation extension units
- Local (county and urban) recreation agencies
- Universities.

In general, the sessions on the program followed the format outlined below:

1. A general topic for discussion was listed
2. A panel of speakers presented papers on the topic
3. A brief question and answer period followed each speaker
4. Assigned critiquers reviewed papers prior to the presentations, developed key questions about the papers, participated in the question and answer phase of the program, and comprised part of the panel during formal discussions
5. After papers were presented in a given topic area, all attendees participated in one of four small-group workshop discussion sessions. Each discussion group had a previously assigned discussion leader and a recorder. The objective of each group was to further discuss the papers presented and to develop recommendations and questions on the topic.

6. Workshop groups returned to the main auditorium and discussed the topic with a panel composed of the session speakers and the critiquers of the speakers' papers.

Based on reactions after the Workshop, the program and format for the proceedings were judged to have been highly successful. Practically everyone in attendance had an assigned role as a speaker, critiquer, topic session chairman, discussion leader or discussion recorder. This resulted in a very open and involved level of communication and prevailed upon the attendees to devote close attention to the presentations.

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TOPIC I

INTERRELATIONSHIP OF RECREATION MANAGERS, EXTENSION SPECIALISTS AND RESEARCHERS

ABSTRACTS

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The Managers' Viewpoint: Research and Applicability of Results.--The host of recreation research oriented meetings around the Nation reflects serious problems in communication and dissemination between researchers and managers. Dialogue between these professionals is missing, misunderstood, or minimal.

This paper exposes and explores a few of the "why's" of our dilemma and recommends some possible cures.

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Interrelationships of Recreation Managers, Extension Specialists and Researchers.--Southern Extension educators conclude that recreation research will be more fully used by resource managers when each of the management-research-Extension components function as a team. Teamwork demands mutual respect, agreement on goals and methods, cooperation, and communication. Often Extension recreation education must be basic, causing a significant lag in current research communication and application. However, greater Extension efficiency would result with a) expansion of responsive and relevant research, b) formal mechanisms for Extension-research collaboration, c) larger numbers of Extension specialists and researchers, d) expanded technical support of the county delivery system, and e) development of non-traditional, education-maximizing modes of devivery.

WARE

Relating Recreation Research to Management Decisions.--There are well-known difficulties in doing directly applicable research, communicating research results, and in applying research results in practice. Some of these difficulties stem from unclear specifications of the roles of managers, extension specialists and researchers. Additional difficulties stem from lack of a common framework for discussing management decisions, how information is ideally used in management, and hence, the role of research in providing information useful in management. Management science provides an appropriate framework. This framework provides a basis for assessing the current state of the difficulties in recreation resources management and research and for exploring some general possibilities for improving the relationship.

THE MANAGERS' VIEWPOINT: RESEARCH AND APPLICABILITY OF RESULTS

Richard L. Cottrell[1]

Abstract.--The host of recreation research oriented meetings around the Nation reflects serious problems in communication and dissemination between researchers and managers. Dialogue between these professionals is missing, misunderstood, or minimal.

This paper exposes and explores a few of the "why's" of our dilemma and recommends some possible cures.

Additional keywords: Recreation research, research application, research communication, extension programs, research dissemination, forest recreation, research evaluation.

INTRODUCTION

If your fantastic research findings were in great demand in the market place, we wouldn't be attending this workshop!! Nor would we have met last fall in Estes Park, Colorado; or at Brandon Springs, Tennessee; Athens, Georgia; Washington, D.C. or other places. Research findings aren't known to a majority of recreation managers; aren't available in a usable form; can't be understood when they are available; and, most of you know it! Thus, we are joined together as friends and countrymen for candid exchanges and to seek ways to improve.

As a prelude to my taking up the big stick allow me to provide a mini-self profile. With it I hope to soften a bit the upcoming blows.

I'm a patron of your science and your art--a depender upon your sage findings--an ardent seller (disseminator) of your goodies and your recommendations (that is, if I can find any recommendations) to a broad spectrum of the great unlearned--a member of a less than dynamic NRPA Task Force on Outdoor Recreation Research--cooriginator of a similar research workshop last spring at Land Between The Lakes--a frustrated suggestor and designer of research studies--and a fellow who has 5 APPLIED research studies (with 4 universities) going on in his area as he prepares this paper.

My ever expanding sharing of ideas and mistakes with--the academic community, the private sector, 15 or so agencies in the Federal park realm, countless state recreation folks, involvement in 6 or 7 professional societies, 15 years in the USDA-Forest Service fighting with timber beasts and other assorted recreation antagonists, my association with the new breed of cat you call the disseminator, and my work with researchers from the Western Hendees to the Southern Swinfords, James, and Cordells, to the Wagars, Chilman, and Burys provide the basis for my questions, criticisms, and comments.

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Ken Cordell asked me to explore with you some of the all too common dialogue between researchers and managers:

- "Researchers are arrogant." "PhD's look down on ground grubbers who have less educations."
- "Managers don't read what we write."
- "Managers don't take time to study research results."
- "Researchers keep talking about their poor reward system."
- "Managers aren't interested in doing things better."
- "If the scientific method doesn't fit the problem, research shouldn't be conducted."
- "Managers are dumb."
- "Researchers don't have common sense."

These excellent quotations could be followed with a host of equally worthless sayings. Since, as a manager-administrator, I've worked with research friends in resource agencies and in the academic realm, I can say folks involved in recreation research are generally top drawer. However, you've asked for candid criticisms so, let's explore a few.

HOW MANAGERS PERCEIVE THE EXISTING RESEARCH SYSTEM

Why is it managers and other field people aren't clammering for your fantastic findings? Perhaps we can find part of the answers in this series of introspective questions. Is your research geared to the urgent-immediate needs of managers? Have you presented (packaged) your results so they will sell? Can managers understand what you've written? Have you geared your writeup to management people or is it geared to fellow researchers? Do you aim at publications of interest to managers or publications of interest to no one? Do you describe the problem then prescribe the cure with step 1-10 recommendations? Did you work with management personnel in describing the problem or did you do a fine job without their help? Do you measure success with the number of articles printed and/or the number of pamphlets available for distribution? If your answers to these questions (or at least most of them) are yesses you pass--read no more!

Let's get back to your understanding of managers. They come in all sizes, shapes, colors; are one of 2 sexes; are generally overworked and--sad to relate--aren't waiting on you to save them. The writer has 20 years in 2 Federal Agencies, (16 in recreation), is colorblind, bald, 40ish, is a graduate forester with "0" hours in outdoor recreation, works 6 + days/ week, uses research data frequently and enjoys his job. If you're interested in "ringing my bell" with your research--get to know me, my interests, my possible research needs, and the constraints of my job.

You somehow must make a genuine, concerted effort to understand the job challenges of at least the spectrum of managers in your research realm. What are you doing or what is your agency doing to see to it you have the opportunity to gain some experience in the exciting field of recreation management? Some of the most successful research I know of is being carried on by former managers or researchers who have taken time out to work in management.

A few weeks ago a research scientist located at a prominent northeastern university called and asked for my help. I was asked to be the state coordinator for his research needs questionnaire. This was to go to educators, private resort owners, other Federal and state administrators, key folks in user groups, recreation equipment suppliers, etc. "Why me??" "You were recommended for your extensive knowledge of recreation professionals in the state." Ho? I was busy, busy; but I would, when the questionnaires arrived do my best to help.

The questionnaires arrived on June 16. They were to be returned FROM the respondents by June 20! My first opportunity to review mail of less than Congressional urgency was July 7!! About this time, I received a less than friendly reminder from the researcher telling me the 15 respondents were tardy indeed!

My interest in working with you kept me from throwing this correspondence including the coded questionnaires into the nearest round file. We selected a broad cross section of respondents across the Commonwealth asking them (with a personal letter) to do me a favor by filling out the forms as soon as their busy schedule permitted.

Did the researcher understand the manager at his busiest time of the year--pre-July 4th!? Remember, I'm your friend; how would others less friendly have responded? Researcher arrogance--no; researcher insensitivity spiced generously with the flavor of ignorance--yes.

"The interpreter or disseminator--he will save us!" Extension Service personnel, recreation specialists in the Soil Conservation Service, BOR professionals, and even folks like me spend considerable time telling others about research findings. It seems now, though, these professionals are to be the prime linkage between the researcher and the manager. This is a dandy scheme, one I'm sure which will be covered well, indeed, by the following speaker. If it works, the researcher can take even less responsibility for providing relevant answers in understandable language.

The extension specialist is part of the answer, but asking him to do a job you've failed to do won't help our common dilemma.

Of all the recreation research knowledge gathered here in the Eastern U.S. I find SEFES Research Note Number 171 the most needed and useful. It is Dr. Ripley's February, 1962 study entitled TREE AND SHRUB RESPONSE TO RECREATION USE. If deep-rooted young hickories are well suited to high impact use and shallow rooted species like scarlet oak, hemlock and white pine are poor risks, a knowledge of these findings is important across the eastern United States as a guide to saving tremendous amounts of maintenance dollars.

Yet, in my field trips with professors and students from countless universities and my lectures at maintenance conferences this 1962 information comes as a complete surprise. It's obvious the system isn't properly geared nor is it properly aimed.

Do you know there are over 90 agencies; commissions, committees, etc. in the Federal Government alone dealing with outdoor recreation? Do you know there are now over 300 college curriculums dealing with outdoor recreation in the United States, the majority of which have little or no resource orientation? The professors and students in these schools, the managers they've already produced, as well as recreation personnel in the previously mentioned Federal recreation sector, and countless other professionals and technicians are your market. Are you aimed at these folks or are you aimed at all?

Are you making an effort to find out the actual needs of managers? Research Needs Surveys are beginning to pop up from several sources. They key in on physical and social carrying capacities, economic benefits and other broad items, but I doubt if they will really help much in your quest to sell "products" to managers.

A few months ago I was asked (or better yet told) to sit down and make a laundry list of research needs for Land Between The Lakes. To my surprise, my hurried list included over 109 separate items. Some required basic research on the specific, but most of the items I listed could have been applied studies at the master's level. Once you learn all about that manager, force him to discuss his needs, then follow through and help him.

Are your research efforts directed at something useful? I know of graduate students at 2 universities who are still studying "overuse" and the 26 variables to good campsite design. "Overuse" is more likely Poor Planning - Poor Design and/or Poor Administration; and, the 26 variable scheme will have "0" utility to designers and managers alike. A few years ago the Forest Service, with yours truly as an accomplice - made extensive studies concerning grasses best suited to plant in areas of high impact (around picnic tables and camping pads where grass doesn't belong). This study, like the overuse studies, rest studies, and the 26 variables of site design are a waste of time and effort. They do not enhance your credibility or your appeal in the market place.

Considerable time was spent (to the amazement of management personnel) at the Estes Park Conference with researchers talking about their poor reward system. Management folks were turned off by the researcher pleas for better rewards. This was unfortunate, as the researchers were asking us to encourage their administrators to rate them on the amount of extension and dissemination they do as well as their output of scientific data.

A past history of available research grants together with an interest by several Federal and state agencies in recreation research have combined to give some research folks bad habits. The economy has plunged with resulting mini-budgets for research. Research organizations have been drastically reduced or eliminated entirely yet, the 48-50% academic community rip offs for overhead are still much in evidence. Had your attitudes and your products have been top drawer over the years managers might have given you a better position away from the sharp cutting edge.

Don't be too sure "all" managers don't read your dandy findings. I was chided a bit about one year ago by a research friend when I mentioned the need to find out just what kind-type-size-shape of campsite or campsites users preferred. "If you had really read my findings in a 6 year basic research study of 100 campsites in a N.F. campground in the Appalachians, you'd have the answers to your questions" sez the researcher.

After a bit of thought I said the study wasn't applicable to my original question. Seems I had designed the 100 unit N.F. campground; laid out all of the campunits (with little or no variety in size, shape, or type); laid them all out poorly by today's standards; and helped design his research study many years ago before he moved into the program. For some reason the subject wasn't raised again.

Professional societies at one time may have held the key to a part of research dissemination. NRPA planned to move into the field with considerable force. This didn't happen nor does it appear NRPA can take a strong recreation research leadership role. Certainly, it would be difficult to say SCSA and the SAF have been excellent environments for recreation and recreation research. Seems to me and many others BOR should accept research promotion and dissemination as one of their most important jobs.

As you know, BOR is beginning to move in this direction. It should and it must; but BOR needs our strong backing to meet their responsibilities. During our Brandon Springs Outdoor Recreation Research Workshop, a BOR representative said the research environment was better, some funding for basic and applied studies was available, and more personnel had been given assignments in this important job.

Let us resolve here to help our BOR friends build on this mini beginning and to help them become the outdoor recreation research influence they should be.

Finally, lets take a look at the "Publish or perish" syndrome. More often than not research language and the paper, magazine or other medium selected isn't geared to the potential ground - grubbing user --; but it does give the researcher a continued lease on life.

Perhaps we need to shake the foundations of the "reward system" by rewarding researchers based on the amount and kind of substantive help they provide the practitioners. This would provide the environment for a real love-affair.

As you'd expect after all this friendly harassment, I have a few recommendations:

1. Make specific recommendations concerning use of your research. Recreation Research policy (when I was in the Forest Service) said the researcher would make his findings known. He would not make recommendations! Your products will never sell without your willingness to climb out on the limb with us.
2. With considerable sincerity learn as much as possible about your potential clientele. Court the managers and administrators and know if there's a difference.
3. Help us in all possible ways to move the BOR into a strong - highly respected role as National coordinator of Outdoor Recreation Research. Encourage them to move high caliber personnel into their research coordinating positions.
4. Move with vigor into the APPLIED research realm.
5. Help provide graduate students with useful - saleable study opportunities.
6. Don't use extension folks as your crutch in selling your findings.
7. Broaden your professional horizons by joining and helping promote viable recreation organizations. NRPA or one of its branches needs your help. You'll find a whole new real world of recreation managers there. My advice is to join a local state recreation and park society. The members will readily buy the useful "products" of fellow members.
8. Educators should consider forming a special research flavored organization under the umbrella of SPREE.
9. Court the leisure products community and user organizations. Researchers and managers have long been reluctant to move in this direction.
10. Don't talk about your "reward system" in mixed company. It's a red flag word series to most managers.

11. Additional emphasis must be denoted toward human development, well-being, and creating a positive self-immage. Time spent on trying to find the best grass to grow under picnic tables should be directed toward betterment of man's well being.
12. Next time you ask a manager to "tell it like it is" pick someone who doesn't know you so well!

A CRITIQUE OF THE PAPER ENTITLED

"THE MANAGER'S VIEWPOINT: RESEARCH AND APPLICABILITY OF RESULTS"

K. F. Schell[1]

The one obvious, predominant conclusion, with which I agree, is that the relationships between researchers and managers must change to generate more mutual understanding. There are, however, some implied reasons for the existent relationships which I may not be able to support, e.g., researchers might be arrogant and look down on managers, and they complain about a poor reward system.

Another point of agreement, and one which merits considerable, serious discussion is the absence of recommendations in research reports. As indicated by Mr. Cottrell, U. S. Forest Service policy in the past has ruled against the inclusion of specific recommendations in a research report. Other research organizations have this same policy. Recommendations are assigned to the extension arm. Should this policy or procedure be changed?

Mr. Cottrell has presented us with a list of "introspective questions" which I think are excellent guidelines to our investigations of researcher-manager relationships. There perhaps could be some additions, but this list along with his 12 recommendations should suffice for the time available to discuss them at this workshop.

One additional point of agreement before posing some questions: the role suggested for the Bureau of Outdoor Recreation should be assigned high priority. This role is included in the original mandate for BOR by Congress and is necessary to an efficient and effective regional and national outdoor recreation research program. I suspect Mr. Cottrell will be challenged, I think he should be, on his implicit questioning of BOR's competence in evaluating research proposals. A worthwhile exercise might be to examine the proposal and the projects he refers to and have a determination by "some of this group" as to their similarity and the merit of the proposal. Such an approach gets very close to personalities, but this cost could be exceeded by the benefits of such a case study.

Returning to the subject of manager attitudes and reluctance to consider, accept, and implement research findings: I think we must recognize the fact that some managers and administrators do not welcome change regardless of the justification for change. Various reasons have been offered to explain this resistance to change including threats to security; increased work loads; and increased costs, both quantifiable and non-quantifiable, of transition.

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[1] Associate Professor of Forestry, The University of Tennessee, Knoxville.

This leads us to the question of who will motivate managers to implement changes suggested by research. The researchers? It is unlikely that as a group they would accept this responsibility. They would, I think, support a planned effort involving other groups. For example, there is need for research to identify barriers to the implementation of policy changes suggested by research results.[2]

I would propose that administrators and managers who have formal education in recreation are more likely than others to accept results of recreation research. Consider the analogy of a District Ranger of the USFS who has completed a forestry curriculum and accepts most research findings associated with silviculture. (I am not so naive as to think this is universally so.) I have observed that such persons are less receptive to the findings of social scientists involved in recreation research. The author of our subject paper claims zero (0) credits in recreation. However, he has had the equivalent of many such credits in other training programs, professional associations, etc., and can be considered a manager with outdoor recreation training. I suggest that we might find strong correlations between manager receptivity and the age or type of training of managers. I have heard other researchers imply that managers who do not seek out and analyze research results might not be qualified managers. I cannot argue strongly against this position.

Although it may not be appropriate to include the following in this critique, I offer it to insure that it might be given some consideration: during the last five years, public agencies and other organizations which have offered limited and no employment opportunities for young, natural resource managers who have recently completed their training, have created within their organization a serious education, age, and philosophy gap. They are forfeiting the benefit of improved education and training which has been developed by our institutions of learning.

Surely, I appreciate Mr. Cottrell's concern for the "actual needs" of managers. However, we cannot sacrifice our quest for more answers to the questions about carrying capacities and social benefits. Basic decisions about our resources, both land and people, and the resultant planning have a continuing need for such answers--and, for the present at least, a priority.

Very briefly, a point of correction and clarification: the term "rip-offs" used by Mr. Cottrell in his reference to overhead costs at academic institutions is not justified. I must remind him that the guideline for the level of overhead costs is determined by the Department of Health, Education, and Welfare. For the past few years the percentage has exceeded 70. This, however, applies only to those salary costs incurred at the institution, in its offices or laboratories. At other locations the percentage is reduced to about 30. No overhead is charged against costs for travel, equipment, and supplies. Also, in some cases, at least at the University of Tennessee, no overhead or a reduced overhead charge is made. The elimination or reduction may be considered the institution's contribution to the research project.

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[2] Recent inquiries, associated with the preparation of this critique, with researchers in the disciplines of industrial management and sociology reveal that there is some published information about the acceptance and implementation of research findings. Hopefully the Extension Specialist's Viewpoint at this workshop will include some information on this point.

In closing, I would add to Mr. Cottrell's list of recommendations. Perhaps just as important, or more so, for the researcher as getting to know the manager clientele is to know the recreation user clientele. Any researcher in a given recreation activity area should participate in or observe the activity. He should camp, hike, hunt, fish, ski, etc. There are multiple benefits to this procedure.

INTERRELATIONSHIPS OF RECREATION MANAGERS, EXTENSION SPECIALISTS AND RESEARCHERS

Dennis R. Crowe[1]

Abstract.-- Southern Extension educators conclude that recreation research will be more fully used by resource managers when each of the management-research-Extension components function as a team. Teamwork demands mutual respect, agreement on goals and methods, cooperation, and communication. Often Extension recreation education must be basic, causing a significant lag in current research communication and application. However, greater Extension efficiency would result with a) expansion of responsive and relevant research, b) formal mechanisms for Extension-research collaboration, c) larger numbers of Extension specialists and researchers, d) expanded technical support of the county delivery system, and e) development of non-traditional, education-maximizing modes of delivery.

Effective management of natural resources for outdoor recreation must rely on cooperation between managers, researchers, and Extension recreation specialists. Southern Land Grant university recreation education specialists contend that several impeding obstacles must be removed to assure effective communication between managers and researchers and to obtain maximum benefit from research efforts. Needs focus on more relevant southern research; more conscious teamwork between researchers, managers, and Extension specialists; and changes in Land Grant university methods of rewarding faculty, funding short term research, and overcoming hindering agricultural Extension traditions. The situation is further compounded by the youthfulness of Extension recreation programs and the lingering imperative to communicate recreation educational basics to audiences caught in a major information time lag.

Before expanding on obstacles to communication, it is appropriate to examine a simple model of an idealized management system in which research application is maximized. The model focuses on roles played by individuals or groups who form a team concerned with sound recreation resource management. The role model (our goal) may then be compared with real situations to identify existing weaknesses, system disfunctions, and special problems needing attention in the South. From this discussion some means will be identified to strengthen the communication process and improve recreation resource management.

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[1] Assistant Professor, School of Forest Resources and Conservation, and State Outdoor Recreation Specialist, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida. The author acknowledges support of this paper by the southern Extension recreation specialists, all of whom were solicited for opinions or draft reviews.

IDEAL ROLES BETWEEN MANAGERS, RESEARCHERS, AND EXTENSION SPECIALISTS

The simplest resource management system is a manager or team of managers who are familiar with local problems and make decisions in the field. Their decisions may be enhanced by problem and solution comparisons with other managers. When complex situations prevail, a team member may be assigned exclusively to information gathering and maintaining contact with work done by other managers. Otherwise a consultant may be hired to gather and analyze existing information needed for making decisions.

Situations arise in which the collective experience of resource managers and their consultants cannot provide satisfactory information essential to problem solution. A third party, a researcher, may be asked to examine the problem and uncover relevant new knowledge. If the management team represents a large agency or firm, the researcher may be hired to develop a long term program of uncovering new information in support of management. Otherwise the researcher will be housed with a private research firm, a university, or a public research agency and temporarily contracted to perform needed applied research. In either situation the process of application is direct and is contingent only on quality and relevance of research results.

Often management situations are complicated by the necessity to take quick action. There is insufficient time to contract for research, wait for execution, wait even longer for results, and still have to evaluate the results for significance to solving the problems at issue. Hence, the manager relies on his ability to keep informed of current management practices and research that might be applicable to anticipated problems.

At this point, every manager is aware of the knowledge explosion that has transformed today's world. Having limited time to sift research results for relevant information (even if he knows where to look), he may give it up as a futile effort and rely on intuition or wait for relevant information to somehow filter to him.

Land Grant Extension and similar education programs are indispensible in speeding up the process of filtering new knowledge through the management system. Instead of waiting for new ideas to pass in devious ways to the eventual user, the Extension job is to keep informed of new knowledge in order to channel relevant information directly to the manager, to help him understand it, and to motivate him to action.

Thus one role of the Extension educator is to function as a direct conduit of new knowledge from the researcher to the manager. Since few managers have the time and some lack familiarity to digest technical reports, the Extension conduit role is compounded by an obligation to translate, abbreviate, and disseminate the knowledge to the appropriate manager and in an applicable form.

The Extension educator plays other roles also. On request, he may function as a consultant, to gather and help analyze facts needed by managers or planners. His primary objective is to increase effective use of known and new information. He also plays a critical role with the researcher by informing him of management-relevant priority research needs, and collaborating on research formulation and design. All this requires continual communication between managers and Extension specialists, and between Extension specialists and researchers. A similar direct communications link is appropriate between managers and researchers.

It must be stressed that the Extension specialist is more than a two-way research translator and transmitter. He is an evaluator, organizer of fragmented results, and a synthesizor of research as he molds it into guidelines or other adaptable form. The Extension research communicator is more a research organizer, for his job often calls for reviewing conflicting, duplicative, and at times insignificant research in order to separate out a state or local problem-related package of research results and other knowledge. All this is in addition to a co-dominant role of innovator and motivator.

CURRENT RECREATION RESOURCE MANAGEMENT RESEARCH DISSEMINATION BY EXTENSION

Ideal roles of Extension with research and management can now be compared with the present southern situation in order to identify faulty roles. Because real situations are seldom ideal, there should be no indulging in self-flagellation for what may be perceived as failings by comparison to ideals of efficiency. Nevertheless, as a low scoring archer who simply aims at the target instead of the bull's eye, our scores may be higher if we critically evaluate our stance, the way we choose our target goals, and the time and method of our release. Furthermore, for score improvement beyond gains from self evaluation, there is no substitute for open and honest acceptance of critical suggestions by others who know how to play the same game.

Diversity is the rule for Extension outdoor recreation efforts in the South. Few situations are common to all states, resulting in variation in program content, educational subjects, and user audiences. However, it is probably true that throughout the South there is scarce application of current recreation resource management research through Extension efforts.

Most southern Land Grant universities have a state recreation specialist who provides leadership for statewide Extension educational programs in outdoor recreation. Seven of these fourteen university educators are located in community development or similar departments. The others are with school or departments of forestry, wildlife, or recreation. Many are housed in Extension departments separate from their resident instruction-research counterparts and may have less than desireable frequency of contact. Little programming time is available for many resource management topics because nearly all have heavy demands placed on them to provide consumer recreation educational programs and technical assistance related to development of local community recreation services. Community resource development and rural development committees are properly supported in most states. Often there is involvement with park and recreation board or tourist association formation and support, park acquisition and development, general recreation planning, and tourism development.

There typically is little involvement in recreation resource management beyond elementary land and water conservation considerations inherent in establishing community parks and in advisory involvement in some county land use planning. Knowledge of some current recreation resource management research is vital for maintaining professional competency, but demands are quite low for application of this type of research in most community development work. Except on intensive demonstration projects, recreation resource research is seldom used.

In addition to the state recreation specialists there are about fifteen southern Extension forest resource specialists, most of whom are foresters, who have some involvement in recreation resources management research dissemination. Most of these are generalists who list recreation in combination with up to fifteen other forestry and conservation problem areas. Some help with nature trail design and similar forest recreation concerns, but current research dissemination usually involves forest management for other than recreational values. Of course, program emphasis varies from state to state.

In general, recreation research that has been applied through southern Extension efforts has tended to emphasize surveys of characteristics of successful enterprises, economic studies of various segments of the commercial recreation industry, and consumer surveys. In many instances Extension audience levels of recreation knowledge are so modest that educational efforts must be spent in increasing the effective use of common information.

Under these circumstances, basics tend to supersede more sophisticated current research results. Extension deals every day with an information time lag of major proportions. Youthfulness of Extension recreation programs and the necessity to serve all types of recreation information needs further limits the opportunity for the specialist to get below the surface of basic education. In such a climate state specialists can become generalists who have difficulty keeping up with research reading, much less digesting, reorganizing, and rewriting research in a form useful to managers and planners.

BARRIERS TO RESEARCH APPLICATION

Three complex, interrelated problems combine to hinder recreation research application in the South: 1) There is a paucity of relevant southern research; 2) Research, management, and Extension have failed to unite as a team; 3) The traditional Land Grant agricultural research and information system is poorly equipped to handle recreation resource topics. Responsibility for existence of these problems must be shouldered by all groups involved. Neither research, management, nor extension functions can be singly blamed for these barriers, and for some only time and failure to adjust is responsible.

Paucity of relevant research

Southern recreation Extension programs might have more responsive managerial audiences if their educational value were more easily comprehended. Extension has no real uniqueness when the information exchange is common or old knowledge. If undeniably relevant new research results were available through Extension, credibility and acceptance would be greatly enhanced. But, despite the huge volume of recreation writing and research results produced nationally during the last fifteen years, large unmet research needs continue in the South.

There is a glaring lack of research which is relevant to the South, to individual states, their localities, and especially their urban and exurban recreation resources.

Currently there is no ongoing U. S. Forest Service recreation research in the South. Other federal agencies with research capabilities also may have left the southern recreation scene, and very little was done in the past. It is very questionable that Pacific Northwest or northeastern research can be directly applied in the South and especially to Florida's urbanized, peninsular, near-tropical exception to many rules. As recent social concerns shifted to other matters of environmental quality, it would appear that Land Grant universities continued to place low priorities on funding recreation research. Consequently, southern universities lack the manpower and budget to pursue critical state and local research needed for planning and managing aesthetic and recreational resources in a rapidly urbanizing, land use conflict generating South.

With state and local planning, development, and management activities rapidly increasing and recreation research apparently decreasing, there arises an obvious dilemma. Need for the Extension recreation program has never been greater and is growing, yet overall program efficiency and production potential must drop. Research efforts must be expanded and more effective use must be made of existing knowledge. There simply are too few researchers, too little southern research, and too few Extension recreation specialists.

It may be proper to contrast management of local recreation and open space lands with large extensively managed recreation resources such as those managed by federal agencies. Seemingly little research is being provided the planners and managers of these local resources. Their problems differ by scale and use intensity. Management is largely reduced to site maintenance. There are lawns to mow, ditches to clear, roads to maintain, traffic accidents and emergencies to investigate and report, rowdy visitors to control, etc. The resource base beyond what is mowed is often left alone. The forest manages itself. Trails are maintained but high user impact trail-side forests are neglected.

Authority and, by default, concern for decisions in local park management encompass principally operations maintenance. Functionally these are park operations managers, not resource managers. The attention given the site is primarily that required to handle people and counter obvious major people impacts. The more subtle implications of resource management are lost in attention to the crush of visitors, personnel problems, and seeing that equipment is operable. Simultaneously planners continue to devise park allocation schemes based on recycled rules of thumb.

It seems that few local managers and planners are requesting research and even less research is performed. They say their problems are practical, not academic, and they don't seek help from the university. We don't even know which urban resource management needs are most critical because so little attention has been given these resources. Public relations ultimately may be more worrisome to state and local park managers than site resource management. A distinction must be made, however, between the problems faced by park superintendents and the policy makers and managers in main offices. For either group, genuine research is rare.

Failure of the team concept

Two basic failings emerge from an examination of the manager-Extension specialist-researcher team: 1) research-Extension relations function too independently and 2) research is too isolated from management problems.

Research-Extension relations.-- Basic to the Land Grant university system is a team approach between research and Extension, and this team must function if the job is to be done. Research and Extension are not independent functions of the university, despite implications of separate academic and Extension departments for a single discipline.

Resident instruction and research departments have long practiced a subtle snobbery and self-elevated separation from Extension. During the last century, the world at large has given greater status to the inventor or creator of knowledge than to the practitioner. It is a pity that persons who pride themselves in their grasp of the scientific method of logical reasoning have been so gullible as to associate this status with functional quality, causing some to withdraw into self-congratulating, behavior and attitude reinforcing circles. (In fairness, such group criticism must be taken only by the individual, as it applies.)

Partly resulting from this attitude is an assumption of one-way flow, and active-passive roles. Except for a modest amount of passive reverse flow whereby managers and Extension specialists communicate on problems and research needs, the researcher view is primarily of one-way flow: researcher to manager, perhaps through Extension, if application and dissemination is seriously considered. It is true that some more zealous applied researchers are honestly concerned with improving the effectiveness of transmitting current research findings to users, but again this is basically a one-way flow concept.

Formal researcher-Extension specialist communication over research is minimal. There may be an annual or less frequent opportunity for the Extension specialist to discuss priorities during review of research planning. Depending on physical proximity of working areas, there may be opportunity for informal discussion of research needs and applications. Failure or success in communicating and response depends most on the individual personalities involved and on the responsiveness of the system. Little formal structure or incentive encourages the researcher to transmit research to the Extension specialist. Some researchers may even avoid communication for fear of having their results described through Extension education efforts before a journal has accepted their work. The Extension specialist must look to many researchers for information to integrate and route to managers, yet it would appear that few researchers consider their team role seriously enough to send Extension specialists copies of reports or abstracts. Only fifty copies in direct mail would inform each state recreation program leader of major results. It is assumed that Extension has research results at disposal, but probably the specialist doesn't have all he should have.

Research process isolation.-- Managers and Extension specialists claim it is difficult to get many researchers into the field to see problems at first hand; hence some research tends to suffer from the isolated state in which it is conceived. The problem is dual: 1) research is not always on priority problems and 2) there is too little researcher anticipation of the most useful form of results.

The objectives of too few research studies are offered for review by representative users to ascertain their relevance. The researcher or the contracting agency assumes the form of anticipated results is proper, but the ultimate user may require a different form.

Agency designated and contracted research usually includes review of research design and form of anticipated results. However, some applied research formulation avoids a critical review of potential applicability, relying instead solely on researcher opinion. The argument is not for specific application as contrasted with general application, but for greater attention to appropriateness of research and form of results in order to maximize application potentials. This need exists since almost all research must be translated and specially adapted before application.

For example, assume research produced significant results useful to managing lands for different user group preferences, but in order to apply this knowledge, the manager must interview all visitors to find their position on a sophisticated psychological index curve. Had the researcher anticipated application, perhaps an index correlate could have been tested that would allow use of a simplified observation to class visitors in order to manage for group preferences.

Some of the responsibility for poorly applicable results rests with management, for there may be an unwarranted defensive posture or even a reverse snobbery in some instances that prevents manager-researcher communication. This may be demonstrated by managers whose attitudes are characterized by comments such as "Who needs research? It is too theoretical and unrelated to be of any value."

Responsibility may partly rest with the Extension specialist who fails to indirectly educate the researcher about team roles. A young teaching-research person once remarked to an Extension specialist on the same faculty: "What good are you to us? You don't teach classes. You don't do research. I really don't know what you do!" This candid and honest statement demonstrated ignorance of team roles and results of poor communication. The Extension specialist undertook a year-long job of educating the researcher through casual conversation, committee work, badgering him for research information, and demonstration of willingness to help him by reviewing his field interview schedules and research designs in the specialist's area of greatest research capability. One day the researcher conceded: "You know, all this time I thought you were just a guy who told people where to go fishing, but you really have knowledge of recreation resources and their users that is a credit to our School effort. Let's get together and write a joint research project statement."

The point of this illustration is that communication is a two-way street and sometimes the street signs should be re-read. To obtain better, more relevant research, and to have it applied, all parties must be a little more tolerant, more mutually respectful, and teamwork improvement must be actively sought.

In fairness to researchers, it must be pointed out that establishing a solid research base for applied efforts has been a difficult task. Recreation research is centered on a social problem area, and is not the domain of a single discipline. Each discipline has struggled to evolve its own theory. Hence much work has been exploratory and basic with very fragmented applied research gains. It probably is accurate to say that some recreation research is properly too theoretical for managers to use. But managers must appreciate the reason for this and support both pure and applied research.

System inadequacies

Three Land Grant university system inadequacies deter application of research results: 1) The reward system is not designed for researcher-Extension specialist cooperation, 2) Experiment stations have difficulty performing needed recreation research, and 3) The traditional agricultural Extension system is not designed to aid recreation resources management.

Rewards for cooperation.-- Most research agencies make little pretense of response to research needs identified by Extension specialists. The Land Grant researcher must at least pay lip service to Extension suggestions but there is no mandate for cooperation as a team. Performance evaluation is based on teaching and published research. Time spent in the field is time taken from classes or research. Furthermore, budgets usually are not adequate for exploratory field work.

Research relevance is ultimately of little concern when promotion is considered. Importance is placed on acceptance of published research in peer journals. Slight incentive is offered to publish for management; instead, this takes time away from "serious" writing. This usually places the whole burden of cooperation on the Extension specialist.

Experiment station problems.-- Many Extension generated research needs are for short term studies. It is difficult to get research information in time to meet needs. Research planning usually is too involved and for too long a term to allow placing a researcher on the job when needed. Often studies of less than one year's duration are needed and for such periods most budgets won't allow researcher involvement except at some loss to ongoing efforts.

It appears that recreation research has been given low funding priority. Food and fiber concerns are still the primary concerns for agricultural experiment station research. Researchers may see needs for research, but there is seldom "loose" money for projects. Studies must be dove-tailed into appropriate ongoing long-term projects, if they can be found.

Agricultural Extension traditions.-- The reason for being of the Cooperative Extension Service is infusion of current university knowledge into the arteries of each state's working information system. The strength of Extension is the system of county offices throughout each state. The local information user has a campus of his Land Grant university in his county with university faculty to assist him.

However, few land use decision makers, planners, and renewable natural resource managers seek research or other information on other than agricultural matters from the local Extension office. The information and continuing education potential of the county office is publicly stereotyped with largely an agricultural subject identity and is internally limited by agricultural expertise and habit.

The problem is that natural resource management concerns other than agricultural are foreign to the training and philosophy of agricultural Extension faculty who staff the local offices. There simply are few at the local level of Extension who are effective in communicating natural resource management information (recreation, forestry, or wildlife).

Therefore, there is little reason to expect anything but a very weak delivery link between the university or state recreation specialist and the local resource manager. Though unfeasible to some, a major task of each state recreation specialist is to maximize the delivery system by encouraging and training the county staff. Most county staff usually respond to recreation information requests with a letter or call to the state specialist who handles the problem. For example, most vegetable crops Ph.D. or Masters degree holders prefer to deal with vegetable crops; thus, they often force the state and area specialists to function as "county recreation agents at large," not as true specialists serving a network of educators. The result is that state recreation specialists and area community development specialists may have little more than superficial ties with the county system. Also, little current research finds its way to managers directly through the county system.

The Land Grant system provides research for agriculture and an Extension delivery system for agricultural resource managers. Little formal support is provided for natural resource concerns which are peripheral to production agriculture. On the other hand, much research in wildlife, sport fisheries, and recreation is performed outside the traditional Land Grant agricultural research channels. U. S. Forest Service recreation research is funded externally to agricultural research, as is that of the Tennessee Valley Authority, Corps of Engineers, Bureau of Outdoor Recreation, Fish and Wildlife Service, etc. Other state and local agencies are sought by resource managers for their wildlife, forest and allied recreation resource research information needs.

In Florida, private consultants, the district conservationists of the Soil Conservation Service, the county and urban foresters of the Florida Division of Forestry, and the local management specialists of the Florida Game and Fresh Water Fish Commission are primary local sources of recreation resource management information. Each of these agencies is both a management and information delivery system, with its own internal channels of updating and continuing education of field personnel. Furthermore, typically when Land Grant university research and information is used by these agencies, it is without benefit of formal linkage through Extension.

With a few exceptions, most southern states have similar parallel agency systems of recreation resource information dissemination. The Extension dilemma lies in the reward system. For the state and area specialist to serve the parallel agency system is to by-pass the local Extension office and admit system failure. Since the specialist receives his reward from serving his system there is little personal incentive to divert his time and effort into the higher efficiency recreation delivery system.

RECOMMENDATIONS

In conclusion, a number of positive steps need to be taken in order to overcome the obstacles discussed. The following outline lists several possible partial solutions to the problems at hand. Not all of these fit each southern state, but it is intended that these recommendations serve as a catalyst for finding ways to improve recreation research application in the South.

Research improvement

Expansion.

Support renewal of southern recreation research by the U. S. Forest Service and other federal agencies.

Support development of recreation research staff in southern Land Grant institutions.

Increase regional, state and local research, especially that with urban orientation and regional planning application.

Responsiveness - flexibility.

Explore ways to fund short-term recreation research, perhaps by inventing a new support project category to include an array of studies.

Seek efficient ways to allow short-term transfer of Extension or research assignments and budgets.

Relevance.

Increase research and operating expense budgets and time flexibility to allow more exploratory work and field study of manager problems.

Establish formal requirements that all applied research plans be subject to manager-user review.

Encourage researchers to anticipate and accommodate operational use of applied results, with particular attention to organization of research design for ease of result application.

Researchers should be encouraged and rewarded for efforts to publish and otherwise communicate results to users.

Joint research-Extension appointments are needed.

Research-Extension team improvement

Manditory measures must assure formal and functional cooperation between members of the research-Extension team.

All channels must be opened to increase two-way communication between research and Extension.

Joint Extension-research appointments should be increased to dissolve certain superficial distinctions between functional roles.

Extension and research groups should be co-located with budgetary and program functions under common administrative control.

Extension specialists must continue to improve informal educational programs for researchers to impart better understanding of joint roles.

Based on user requirements of the management-Extension-research team, a centralized national and regional recreation research monitoring and coordinating agency is needed. An outgrowth would be a readily available management information retrieval system.

Extension improvement

Manpower.

Each southern Land Grant university should have at least two state recreation specialists: a resource specialist and a community development specialist.

Area recreation specialists are needed to work with managers, developers, and communities.

Expansion of student assistant and technician support budgets should be considered to help stretch extension specialists' capabilities.

Administrators should continue to upgrade research communication by continuing to hire specialists having research capabilities as well as educator qualifications.

County support.

State specialists must place increased emphasis on in-service training to improve county capabilities and maximize efficiency of the statewide information delivery and educational system.

A better job must be done of supporting local offices with current usable research information and publicizing the information and its local availability. (This should increase visibility, credibility, and image of the system.)

Conscientious adherence to a planned program of work will allow less county fire-fighting and more profitable attention to research application efforts and building county capabilities.

Research communication

Extension must undertake research on its effectiveness in recreation research communication and aiding application.

An Extension administered program is needed to build manager understanding of values of and enlist support for long-range, large-scale, basic recreation research.

Regional recreation Extension communications are needed. Focus should be on cooperative program development, evaluation, publication, and data sharing. An automatic report-activity-abstract sharing system is needed.

Extension must formally address the need for audience expansion within non-traditional channels. Support communications links should be established with agencies having local delivery systems now used by recreation resource management professionals.

Extension recreation efforts might benefit from a de-emphasis on information delivery services in order to capitalize on the educational role of the university. Especially needed are intensive courses and other means of aiding in vital continuing education of competent resource professionals.

A CRITIQUE OF THE PAPER ENTITLED "INTERRELATIONSHIPS OF RECREATION MANAGERS, EXTENSION SPECIALISTS, AND RESEARCHERS"

L. A. Lindquist[1]

Dennis Crowe's discussion of interrelationships between the three roles proceeds in a logical manner and presents a very clear analysis of the state-of-the-art. The paper does not disclose any new research, but describes the situation with emphasis on the author's personal experience as an Extension Specialist with a Land Grant university. From this somewhat limited standpoint, the paper is thorough and comprehensive.

An idealized management system in which research application would be maximized is described. In this system the Extension educator is seen not only as the conduit for new knowledge, but as having the obligation to translate, abbreviate, and disseminate knowledge; to gather and help analyze facts needed by managers; to collaborate in research formulation and design; to identify relevant research needs; to synthesize research by organizing fragmented results; and to serve in the role of innovator and motivator. This looks like a very heavy responsibility. We can see many of these functions in our conception of extension, but believe that most of them are shared by both the researcher and the manager as well. Research cannot be relevant and useful if the Extension specialist is the only one who can tie it to the real world.

Crowe seems to feel that the southern situation is unique with regard to diversity of programs and situations, and that the traditional extension system designed for disseminating agricultural information can't cope with recreation resource topics. In our experience these comments could apply equally in other sections of the country and do not need to be qualified as being uniquely southern.

We agree that County Extension Agents are seldom oriented to disseminate recreation research but feel that his weakness is no less applicable to other areas of knowledge which Land Grant universities might be able to disseminate. How do miners, social workers, and bankers keep up-to-date? Surely not through the County Agent. We like to view extension (small "e") as a process, rather than as a role, which fits into every discipline where new knowledge is being defined. In some areas this process can be internal, such as within a State or Federal agency, where a new system may be developed, adopted and then disseminated to managers and field workers. In most such cases there is an educational process involving all of the characteristics of extension work.

The author does not mention the many external extension-type programs involving recreation resource topics other than those conducted by Land Grant universities. Comprehensive lists of these have been published[2] by the

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[1] Forest Supervisor, Caribbean National Forest and State and Private Forestry Program, Rio Piedras, Puerto Rico.

[2] U.S. Department of the Interior, Bureau of Outdoor Recreation. 1970. Federal assistance in outdoor recreation. Publication No. 1, Revised 1970, and U.S. Department of the Interior, Bureau of Outdoor Recreation. 1970. Private assistance in outdoor recreation, Washington, D.C.

Bureau of Outdoor Recreation. One example of extension-type assistance in the recreation field is the Park Practice Program, which is a joint program by the National Park Service, the National Conference on State Parks, and the National Recreation and Parks Association. This program consists primarily of publications dealing with a range of planning and policy concepts and field maintenance methods. This kind of "extension" vehicle can serve to transmit all kinds of ideas, including interpretation of research results.

We particularly liked Crowe's analysis of the barriers to research application, and the listing of recommendations intended to overcome the obstacles discussed. He has successfully identified the significant broad areas where successful changes might be made to improve the dissemination of recreation knowledge. This discussion tends to have the same limitations mentioned above, however, because of the author's constraint of the extension role to the Land Grant University. Of the problems listed, we only question the first in his list, which discusses the paucity of relevant research. It is true that there is not a great deal of research presently going on in the South, but most of the research we have seen which involves new methods is applicable very broadly. Where empirical data are the sole research result, the conclusions, naturally, are confined to the area where the data originated. We don't think this is the case, or at least are not convinced, when the author does not cite any specific examples.

We're not sure that not having hot new items to pass out is a true limitation either. Recreation is a field of considerable growth, and there are new areas and new managers needing some exposure to older ideas. At many levels, these people have been assigned to the recreation resource field from other disciplines and are in need of basic training using material from existing research literature. Most studies in recreation problems are not yet a full generation old, and there is plenty of disseminating to be done among those of us who have not yet gotten the word on basics.

We'd like to see more examples to support some of the generalizations by the author, such as:

> "Diversity is the rule for Extension outdoor recreation efforts in the South."
> "...recreation resource research is seldom used."
> "...large unmet research needs continue in the South."
> "...few researchers consider their team role seriously enough to send Extension specialists copies of reports."
> "...some applied research formulation avoids a critical review of potential applicability."

It's possible that examples could have helped the author to remove many of the qualifiers in his statements, thereby giving them more strength.

RELATING RECREATION RESEARCH TO MANAGEMENT DECISIONS

Kenneth D. Ware[1]

Abstract.--There are well-known difficulties in doing directly applicable research, communicating research results, and in applying research results in practice. Some of these difficulties stem from unclear specifications of the roles of managers, extension specialists and researchers. Additional difficulties stem from lack of a common framework for discussing management decision, how information is ideally used in management, and, hence, the role of research in providing information useful in management. Management science provides an appropriate framework. This framework provides a basis for assessing the current state of the difficulties in recreation resources management and research and for exploring some general possibilities for improving the relationship.

Additional keywords: Researcher's role, decision framework, information needs, research and development, management by objectives.

INTRODUCTION

> "It is worth remembering that the only real source of power in the world is the gap between what is and what might be. Why else do men work and save and plan?"
>
> John Rader Platt

In this paper the emphasis is on management of the natural resources and the related "delivery systems" that are the focus, environment, and means for providing outdoor recreation opportunities and hence human benefits. Hopefully it will be possible, by emphasizing the human benefits to be produced, to avoid potential criticism of either narrowness or bio-centricity, and by emphasizing the management of the resources as contrasted with the delivery system (i.e., "managing" the people who come to reap the benefits) perhaps the author can stay closer to his area of expertise. (This is not to de-emphasize the problems or opportunities in these other aspects, some of which are to be addressed in other papers here.) An example of a question that relates not only to the resource system but to the whole delivery system is: What is the output that we should manage for and measure when we manage wildlife habitats? Until we have specified our objective in providing satisfying outdoor recreation experiences for hunters and outdoor recreationists whose use of wildlife is non-consumptive, we cannot even decide how to measure our output from the resource system, or specify ways to evaluate our performance in cost-effectively satisfying the objectives. Here, let us for the moment, however, rest these weighty questions while we concentrate on a framework within which we may do more relevant research to provide useful answers.

Although roles of managers, extension specialists and researchers have been discussed in earlier papers by Cottrell and Crowe in these Proceedings, there seems still the likelihood that we do not all have similar ideas about either what is, or what should be the roles. If we had a clearer definition of what the whole job of resources management is, it might help us to decide which parts of the job are best left to managers, to extension specialists and to researchers. We do all agree that there is need to share the burden and avoid the "we-they" syndrome.

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Whatever the decision problem is, it is usually relatively undefined and poorly understood by those concerned. What information is needed to solve the problem is far from clear and certainly there is little basis for setting priorities on the gathering of information whether the manager, extension educator, or researcher is to gather it. In fact, many management decision processes seem to be developed to be information independent, and the decision would not be influenced one way or the other even if much more information were available. (This may be appropriate, but it does not fit the value set of most researchers.) Suppose we all agree to work in absolute sincerity to try to define the research most relevant to application. What would we do? Do we agree? How would we cope with the variation among managers? Among uses of the same information? Among expertise areas of researchers? How would we arrange to satisfy need for fundamental and futuristic research?

Clearer communication and operationally useful definitions of roles and responsibilities should be possible if we accept a systems-analytic or management science framework for resources management. This is not a new idea and is a modest proposal. However, it might be useful to sketch it in this context.

We want to consider how to use or manage lands so as to achieve some objectives, e.g., producing services, environmental amenities, outdoor-recreation opportunities, raw materials, etc. Management of land for any of the products or services that people desire from it involves a complex biological, physical, and social system. As we all know, various uses of the land and resources are usually not entirely complementary or compatible; they are often conflicting. This drastically complicates land-use planning and land and resources management because, at the very least, the manager must predict the effects of alternative mixes of natural and managerial inputs on the production of each resource, or on provision of amenities or other values. Then, based on these predictions, and an appropriate decision or optimality criterion, he must decide on a "best" input mix. To do this scientifically he must have an adequate quantitative model of the forest system: that is, he must have a set of relationships permitting:

(1) prediction,
(2) determination of optimum input mix, and
(3) control of output through manipulation of managerial inputs.

This is, of course, true of any system providing outdoor recreation services, regardless whether the context is a multiple-use forest, one with emphasis on natural resources or a quite different one such as a park playground.

A FRAMEWORK FOR INFORMATION GATHERING AND USE

The Management Decision Problem

One relatively complete framework for viewing forest-resources management as a set of decision problems is described in the book "Planning Research for

Resource Decisions".[2/] (This paper borrows heavily from that book.) The framework is essentially that of management science, or operations research, and is closely related to classical scientific method.

This framework built around the idea of a "management decision problem", provides one construct for considering how research activities ought to relate to planning and management activities. People have resources planning or management decision problems when they are considering using resources to achieve their objectives, and when they seek to choose from a set of alternatives the most appropriate action to achieve that objective.

Specifying the problem.--A management decision problem exists and is fully specified when the following are identified and/or defined:

1. The decision-maker -- the person or group who has the problem.
2. The decision-maker's objective -- the desired outcome or output. The objective may be dollar income, or recreational satisfactions from a specific cash outlay, specified physical outputs from the resource system, etc.
3. Managerial alternatives -- at least two unequally efficient courses of action (specific sets of managerial inputs) which have some chance of yielding the desired objective, and doubt as to which choice is best.
4. The decision environment -- the context of the problem, external or uncontrolled factors that affect the solution. (These contextual factors may constrain the alternatives, influence the output, or influence the choice of optimality criterion.)

Information in problem solving.--The general objective of a land, natural resource, or recreation services manager is usually to supply that information which will contribute most toward helping landowners, or decision-makers representing them, to achieve their objectives efficiently.[3/] When the decision problem has been carefully analyzed, it becomes clear what information is necessary to solve the problem. To "solve the decision problem" is to choose the alternative that will most efficiently satisfy the objective. This is also the "optimization problem". It involves applying an "optimality criterion" (sometimes inherent in the statement of objective, e.g., obtain maximum) via an "optimization technique" to determine the "most efficient".

If we are to apply scientific methods to solve such decision problems directly, then we require a decision model. (Commonly the model will not permit complete direct solution but will incorporate only some of the most important aspects of the decision problem.) A decision model, in standard format, contains an "objective function" that relates levels of outcome (the objective) to the alternative levels of inputs--both those inputs under managerial control and those uncontrollable but part of the "environment". Functions that

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[2/] Stoltenberg, C. H., K. D. Ware, R. J. Marty, Robert D. Wray and J. D. Wellons. Planning Research for Resource Decisions. Iowa State University Press, Ames, Iowa. 1970.

[3/] The resources manager will sometimes be the decision-maker by proxy for the owners of the resources. There will always be some decisions delegated in the hierarchy. However, we find it useful, for purposes that will be explained later, to speak of decisions at a single level and with a single final decision-maker who is the owner of the resources.

specify any constraints or boundary conditions on the outcomes, inputs, or relationships between them are also required. Constraints determine the boundary between the set of alternatives specified as available to the decision-maker and related aspects of the context that are not to be considered as alternatives in the particular decision problem. (Such boundaries may be between decision levels in the organizational hierarchy.)

Then a "measure of performance" or "optimality criterion" is required by which the value of a decision, i.e., outcome associated with a particular alternative, is judged. This specifies what is considered optimum, "best" or "most efficient". Finally, one needs an "optimization technique" by which to determine what alternative is "best", i.e., what produces the "highest value" outcome. It is understood, of course, that the decision-maker will apply his judgment in taking the decision based on the always imperfect model and analysis. That is to say that the model and analysis aid decisions rather than make decisions.

Information flow.--We all recognize that there are many difficult-to-fulfill information needs in planning and management of lands for provision of recreation opportunities. For example, one may ask, "How can we possibly achieve satisfactory forest land management if we do not know how alternative land treatments regimes will affect levels of forest-user recreation, general environmental quality, quality of recreation-visitor satisfaction, timber growing-stock levels, soil and water quality, and wildlife habitat and populations". These kinds of information need come under what we refer to as response models or relationships, estimators for prediction of output, or production functions. These are the functions that relate output to input, and ideally, optimization techniques are applied to these functions to determine the "best" schedule of inputs. A common objective of research studies is to derive these relationships.

Role of Managers

In discussing research and management of wildland resources it is necessary to remind ourselves that we are speaking ultimately about the wants and needs of people. It is perhaps not necessary to remind outdoor recreation managers and researchers of that--your focus has been more on peoples' wants. Nevertheless, there may be danger of focusing on short-run wants. So let us be reminded that when many human wants can be satsified more effectively by using recreation resources than by using other means, then recreation resources assume greater value. But when there are other ways to satisfy peoples' needs more efficiently, the importance of recreation diminishes. This relationship is important because it clearly shows recreation resource management to be a means to various ends rather than an end in itself. The relationship appropriately places the focus on the persons to be served and on the wants to be satisfied by recreation resources management.

The critical importance of efficient management also becomes obvious. And it is indeed because efficiency is so important that we have resource managers. The ability of outdoor recreation managers to help satisfy human desires efficiently determines the proportion of capital and human resources that will be spent on outdoor recreation rather than on other activities which could also satisfy some of the same human desires.

Thus, as the manager learns new uses for his resource, he will be making a greater contribution to society. Simultaneously he will be making that resource more valuable and as he makes management operations more efficient, he will again be increasing his contribution to society.

In performing his professional activities, the recreation manager assists his clients in four major ways:

1) First, he will help them identify and clarify their objectives. For example, the manager may help identify the various personal satisfactions that the owner is seeking in managing his land.
2) Second, the manager identifies for the client the various alternative ways of achieving the client's objectives.
3) Third, he helps his client evaluate or compare these alternatives, i.e, he helps him select the most promising or most efficient opportunities for achieving his objectives.
4) And, fourth, the manager usually supervises the subsequent activities to implement these decisions.

In other words, the recreation resources manager is a professional consultant who helps his client identify and solve recreation resource problems, or who himself acts in proxy to take the decision for his client.[4/]

Recreation managers frequently spend so much time implementing decisions that insufficient emphasis is given to problem solving, that is, to the critically important phases leading to the decision to undertake particular activities. This is unfortunate because it is when he is helping his client to make decisions that the recreation resource manager is often making his most valuable and typically professional contribution. Similarly, his greatest contributions in supervising management practices are made in the problem-solving or decision-making role.

Role of Extension Specialists

In the classical model, information needs and requests flow from managers outside of research; through education and extension specialists or applied researchers to the more applied studies; and finally to the more basic studies. Continuous communication between client and manager, practitioner and researcher, and among various kinds of researchers is necessary if both management and

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[4/] There is some risk of communication difficulties from our particular uses of the terms client, manager and consultant. However, it has been found desirable to describe the professional role this way as a reminder to ourselves as professional resources managers, extension specialists and research scientists, not to substitute our personal or professional objectives for those of the owners of the resources, whether public or private. This seems to happen frequently and it is important to minimize the risks. Usage here is in accord with the role of the professions--law and medicine. There the professional is clearly a consultant, even though after diagnosis he may exercise nearly complete freedom as a proxy decision-maker in administering legal defense or medical treatment.

Furthermore we have found it useful to consider a hierarchy of decision-levels, decision-problems and decision-makers and, a similar related hierarchy of researchers. In this framework then a manager or research worker can identify clients at higher levels in the structure, even if he does not relate directly to the final manager's client, the owners of the resources.

research efforts are to be most effective.

Communication and understanding is usually lacking between researchers and managers. The manager often fails to communicate his information needs to researchers because he doesn't understand what types of information that research can provide; and researchers frequently don't seem to provide the information that is most urgently needed to help managers gain greater benefits from the resources for their clients--perhaps because researchers don't understand the client's objectives or management alternatives. Unfortunately, increased specialization among researchers has aggravated this difficulty. For this reason, interest in strengthening the educational function that could bridge this gap is increasing, regardless of whether this function is to be performed by professors, extension foresters, applied researchers, articulate managers, or whomever.

This is the most important traditional function of the extension specialist. He serves as the necessary educator, innovator, information integrator, and communication channel. Informed about current difficulties in both management and research, he is an information broker who contributes to both management and research when he emphasizes the most important aspects of his role. His role in bringing technical innovations into practical application through community dynamics has been carefully studied by sociologists. Hence a great deal is known about how to work with innovators and community leaders to introduce the results of research.

Role of Recreation Research Scientists

Recreation resource science and scientists are valuable to society for the same reasons that the resources and their managers are valuable--they can help satisfy peoples' wants. Just as the resource manager's contribution is measured by how effectively he helps others to satisfy their wants efficiently, the productive value of recreation resource scientists must ultimately be determined by how much their efforts increase the efficiency of the manager.

This, then, indicates the purpose of research. One major purpose is to develop new alternatives for the resource manager. These may be new practices, tools, and concepts, or new products and services. A second common purpose of resource research is to answer questions of fact that arise during management. And inasmuch as resource management is viewed as the process of solving client's resource problems, these answers would be the information needed to solve these problems. That is, research provides the information needed to define or compare alternative means for achieving a resource user's or owner's objectives. A third purpose is to answer questions of fact that arise during research since it is only after some of these basic questions have been satisfactorily answered that the first two objectives can be achieved most efficiently.

Most resource researchers do not directly provide information for the resource manager. And though some researchers may be helpful in specifying the decision-problem and the information needs, managerial problem-solving is not their expertise or responsibility. Many researchers provide information to solve other researchers' problems. Resource research may be viewed as a continuous spectrum of scientists with the resource manager at one end of the continuum. The manager is principally concerned with his client's problem, that of the resource owner or user. But when he lacks the information needed to help evaluate the client's alternative resource practices, he may experiment with several of those practices. Next on the spectrum are the extension specialists and scientists who are attempting to answer the managers' immediate questions of fact, such as resource-use trends, prices, and technologies. (Note that it is common for the extension specialist to deal directly with the landowner client, rather than with a resources manager who serves the client. This tends to cast the extension specialist more in the role of manager--with attendant risks. Some improvement might be made by more clearly defining roles in this area.)

Following the extension specialists and applied scientists are the developmental researchers who create new alternatives for the manager, particularly alternatives that will help solve problems not only of tomorrow but of years to come. Further along this research spectrum are scientists who serve a clientele of other researchers. These scientists, usually from the basic disciplines, provide the facts and relationships needed by other scientists who conduct the more "applied" developmental research. The relationship between applied and basic research is central to the history and philosophy of science and technology but we shall not explore it further here.

Although the ultimate client for all resource activities is the resource-manager's client, the public or private owner of the resources, the immediate clientele of a researcher may be managers or other researchers. But every productive researcher has a clientele to whom he provides research results. This clientele uses his results to solve their resource-management, or research, problems. When the client is another researcher, he in turn is able to conduct his research more efficiently and then provide his clientele with improved answers to help solve their resource-management research or practice problems.

As the distance on the spectrum increases between the manager and any researcher, successful problem anticipation, and hence planning, become more difficult. Although a scientist focuses primarily on his immediate client, his most basic research is really ultimately intended to help solve a resource-management problem. The research planner needs to anticipate that problem accurately. Thus researchers in the basic resource sciences are helping to solve important problems and grasp important opportunities not expected to be critical for 5, 10, or even 20 years. This scientist may have great difficulty in anticipating the correct problem, and on these questions it is not possible to get much assistance from managers who must, quite correctly, concentrate on local and current difficulties and technologies. This is one of the main reasons our society has encouraged extreme specialization, basic research and independent sheltered research environments. This, of course, has obvious and much discussed risks, not the least of which is that even though the problem may be anticipated, attempts to communicate about and possibly alleviate it may not be effective. The "energy crisis" is a large-scale current case in point Researchers in the energy related sciences were saying 20 years ago that the problem would become a crisis, but the communications were ineffective, partly because the information was not at that time useful in solving anyone's immediate problem.

COMMUNICATION AND APPLICATION OF RESEARCH RESULTS

Let us "rap" about our common dilemma--the difficulties researchers have communicating research results, and the difficulties that managers have of applying the results.

As Things Now Are (Or Why We All Behave So Rationally)

Sincere interest in each others's difficulties, expertise, and values, and regular communication about the difficulties of each of us is a necessary first step as earlier speakers have said. However, just being communicative and sympathetic buddies will not, I believe, be nearly enough. And neither will a one-on-one friendly manager with friendly researcher arrangement. There are too many problems, too few researchers, too little money, too frail humans, etc. We are going to have to work together in some common framework and arrangements different than we now have to make much headway. Both managers and researchers have important jobs that take all of their time and energy, and just working harder at it won't suffice.

Permit me to use a personal reference to illustrate. I have a regular and candid communication with a number of resources managers who are personal friends--one is even my brother. These acquaintances do not find my research, or any research, very directly useful, I'm afraid. This is probably neither because the research is necessarily very bad or generally irrelevant, nor because these are poor or atypical managers. On even the most rudimentary analysis, most of their activities and the decision problems they have to solve do not require information of the kind that research can provide. The objectives, policy, and budget constraints of their employers and the nature of both their supervisors and subordinates cause their decision problems to be relatively restricted in alternatives and most decisions not to involve resources information.

If we reflect on our own decision problems we will find that we are not so different. Our problems contain relatively little common information need. This means, however, that it is especially important for us as managers and researchers to find what is common and what has high priority. The professional orientation and decision framework has helped me a great deal in discussing these difficulties both with researchers and managers. It enables a somewhat more realistic and objective understanding of the difficulties of knowledge acquisition and utilization. Otherwise researchers and managers enter the conversation assuming irrational behavior of each other. It is not difficult to describe a construct by which the behavior of both is seen as internally rational--whether or not there is any rationale for relating research to management. Although the supposed irrationalities have been much discussed, not much useful behavior modification has followed--often entrenchment at the poles has resulted.

The reasons for poor communication between researchers and resource managers are not obscure. Most resource scientists are specialists, often working in the basic sciences rather than in applied research. Most of these scientists orient primarily toward their scientific specialty and a clientele of other basic researchers rather than toward practical problems. Unfortunately, this clientele of other researchers is also serving a clientele of basic scientists, thus forming a closed circle of communication, a circle that includes neither the applied scientist nor the recreation resource manager.

Then, too, the work of the basic scientist, because it is specialized, appears narrow to the manager. In fact, it has often, quite properly, no direct utility to managers. In the 1960's more and more researchers oriented toward science rather than practice, and, therefore, their contributions to knowledge may not have direct application to practice. The communications difficulty is an inevitable result of specialization both in science and practice. Both scientist and managers must be aware of the difficulty and take pains to ameliorate it.

To make sure that his research activities will be likely to form a logical pattern and, taken together with those of other researchers, will constitute an effective attack on management problems, the conscientious researcher will seek, first, to be continuously aware of the ultimate objectives of management (and thus of research); second, to visualize the logical flow of information from researcher, to researcher, to educator, extension specialist, to manager; and, third, to be receptive to a return flow of questions from manager, to extension specialist, to researcher.

Similarly to assure that his decision problems are understood and appreciated by researchers, the manager will seek to be continuously aware of the processes, status, and progress of relevant research, of the specializations of the researchers most likely to be able to address his management problems, of those information needs he has which are common with a significant number of other managers, and of the continuum of research activity stretching from the most basic to the directly applicable. It is important and difficult to keep in mind that today's applicable research may rest on a wide base of more fundamental research done in the past in attempts to anticipate management problems. It is equally important and difficult to adequately define decision problems so that the common information needs clearly emerge and so that it is possible to identify which kinds of information can and should be supplied by research.

Barriers to Application

There are numerous barriers to the application of research results, and put conversely, barriers to doing directly applicable research.

Some barriers have already been discussed here and in the earlier papers by Cottrell and Crowe. Let us now consider, within our managerial-decision framework, some additional difficulties.

Level of application.-- There is substantial difficulty in providing information that will be useful at more than one level of application or management decision--or even in recognizing the different kinds of information (and hence research) needed. No one who has thought about it would believe that the same information is required for decision at the national, regional, state or agency policy level as is required for general land-use and resource management allocations or as is required for specific site design. Yet we all tend to forget about levels other than ours (whether we be managers or researchers) and especially to forget that, even if different information is required, it must be possible to integrate, aggregate and disaggregate it rationally through the various levels. Because the framework proposed here fits the hierarchical nature of most organizations and decisions, it should, where decision problems can be adequately specified, assist in overcoming some of this difficulty.

Differences of value sets between researchers & managers.--There are, we all know, researchers who have little or no interest in management applications of research (some of the best are theory builders, and some of the worst are simply pursuing their own interest at gathering assorted facts or creating "chaos in the brickyard" by making bricks that cannot be built into any edifice). Similarly there are managers who "fly-entirely-by-the-seat-of-the-pants", seldom use or require information, and do not want to be "confused by the facts", to say nothing of considering conceptual foundations.

If a scientist answers such a manager's question for which the manager expects some simple factual or yes or no answer with a logical explanation of why the answer must be thus and so, the manager is turned-off. He is likely to think, "I didn't want a lecture, I just want to know the answer". The research scientist places higher value on the general approach to deriving and understanding answers. He assumes that with this knowledge, the manager might next time perhaps recall or even think through the answer. The scientist's reaction is almost to say "Well, if that fact is all you want to know, here's the textbook, dictionary or encyclopedia". Scientists and managers value different approaches to solving problems. Scientists would perhaps be poor managers unless they changed their values and vice versa for managers who would think "getting the answer" a more practical approach to research. We all need to recognize these differences in values and style. They may be important to nurture rather than to erase--though we tend to talk as if not just the differences due to specializations, but also the value differences should be erased so as to solve our communication difficulty and be more effective in bringing research to bear in practice. I do not believe it is possible, even if it were desirable, to erase these differences in subcultures. There are good reasons for the University and research organizations being somewhat independent of day-to-day brush fires. This, of course, should not be taken as license to be irrelevant--but it is often difficult to see what is truly most relevant.

Perhaps the management decision problem framework should help us to defuse the personal-value confrontations and to work together in logical problem-solving mode to attempt to specify just what the problem is and to decide just how we, each with our various responsibilities values and expertise, can best work together toward solving it. (This would not supplant, but would augment, the kind of personal sharing and communication discussed by the previous speakers.) Hopefully, by putting the problem "up on the wall" and setting our mutual objective to specify and solve it, we could at least avoid the wasted energy and negative reenforcement of calling each other unprintable names.

As We Would Like Things To Be

The necessity (and difficulty) of coordinating the efforts of researchers is obvious if an efficient and successful attack on the most important management problems is to be made. When several types of information are needed to solve a problem, failure to obtain just one bit of information may prevent solving the problem, and thus waste the research efforts invested in obtaining the other information. If communication and coordination are effective, managers will be continuously provided with better information to help their clients gain greater benefits from natural resources. With various degrees of success, the needed coordination is achieved in several ways, a few of which will be mentioned to show the diversity of patterns.

When a large amount of research effort can be concentrated on the solution of a particular problem, the problem itself may form the framework for a large research project. The project in turn would be composed of closely coordinated individual studies designed to provide most of the facts or information required to solve the problem. These efforts might be coordinated by a specific project plan that is designed, studied, and agreed upon by all of the researchers involved. Or coordination might be sought simply by developing exceptionally effective communication and close cooperation among the various researchers.

Close cooperation among researchers within the same discipline is also frequently required. For example, several recreation researchers might be working on different facets of the same problem. Each scientist will contribute an important link of information that will be needed to solve the particular problem with which they all are concerned.

Thus, although the diversity in the techniques and forms of natural resources research is great, important relationships among researchers can be derived from the problem they are seeking to help solve. And because of these relationships there is a unifying pattern to the research activities as a whole.

With the complexity of resources management problems, shortages of research funds, and other difficulties we have already discussed, it becomes increasingly necessary to consider new arrangements for shared responsibility among managers, extension specialists, and research. One current approach to the solution of major decision problems that require the skill and judgment of the manager to be augmented by the expertise and outlook of the research scientist is to form specific ad hoc problem-solving teams. Then, following a "management by objectives" format such as described here, the problem is defined, the team's role in solving it is specified so that team members share responsibility for solving it and all have a stake in the outcome, and work proceeds. In this approach it may not be possible to initiate new research, but it is likely that previously developed results can be brought to bear. It is also likely that there will be indications of what kinds of research should be started to help solve similar future problems. An important benefit of such an approach is that not only are the value differences between manager and researcher brought to bear on a task with common purpose but true communication is necessary and natural to the functioning of the team in satisfying its goals. The Forest Service, and no doubt other organizations represented here, are using such approaches with some success.

There are other approaches to sharing the problem solving responsibility and to closing the gap between research and practice. These are being more often used in large industrial and governmental organizations and have become a part of the current literature on management. Suffice it to say here that we need to be more innovative in testing these arrangements for sharing responsibility in recreation resources management and research.

A CRITIQUE OF THE PAPER ENTITLED "RELATING RECREATION RESEARCH TO MANAGEMENT DECISIONS"

Allan J. Worms [1]

"Blame where you must, be candid where you can,
and be each critic the good-natured man."
Robert Burns

Critique of a worthy effort becomes an especially demanding task when the critiquer seeks to enhance the meaningfulness and utility of that effort rather than to merely illuminate its faults. Mr. Ware's presentation is a diligent effort by a researcher to shed light on the conceptual and functional framework in which research may be related to management. Consequently, through analysis of a researcher's presentation, this critique will seek to contribute to solution of the fundamental problem, namely that of improving the application of recreation research for management decision making.

The title of "relating recreation research to management decisions" suggests a content which deals simply with applying research efforts to the character of recreation management problems. However the task before Mr. Ware was in fact much more complex than merely describing the techniques for research-based problem solving. Rather, it deals with the whole system of human, political, and disciplinary infra-structure giving rise to the dual processes of research and management. His assignment involved recognizing that research and researchers function differently and often quite separately from management and managers, even though both groups and both processes ultimately share the same objective. That objective, declared at the outset of Mr. Ware's paper, is "management of the natural resources and the related 'delivery systems' that are the focus, environment, and means for providing outdoor recreation opportunities and human benefits.

With this perspective, I fully agree for we are dealing very much in the sense of research for the purpose of its' optimum application by management and managers. Moreover, the end point, measureable or not, must be an objective of human benefit.

Early in his presentation Mr. Ware points out the need for definition of the "whole job of resources management" and that such an explanation might help us decide who should do what, on "which parts of the job are best left to managers, to extension specialists and to researchers." Within the next several paragraphs he very adequately sets the stage for a framework of information gathering and use. He describes the need for management problem definition, evaluation of management program input (1, prediction; 2, determination of optimum input mix; 3, control of output through manipulation of managerial inputs), and finally specification of the problem. All of this framework, however seems couched in terms of management problem definition by and for managers. At no point is there a definition or framework allowing researchers to come to grips with the management problem, and readily understand it as a researchable problem.

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I suspect that just as managers and researchers exist in very different worlds of day to day operation, there also exists two very different lines of communication pertinent to their respective fields of operation. In short, I feel this paper has ably identified the perspective of research application and has established a conceptual framework for problem specification for the manager, but has not provided for derivation of the research problem in researcher terms which would enhance the potential for accurate research and its' ensuing application. In an earlier presentation by Crowe, it was noted a basic failing of the manager-extension specialist-researcher team is that research is isolated from management problems and that the "researcher view is primarily of one-way flow; research to manager, perhaps through extension." The building blocks upon which the reverse flow may be achieved are still lacking.

Ware's discussion of the role of managers raises several issues which may be disturbing to managers and which may mislead our appraisal of the importance of the management task. To paraphrase, he sets the priority of management in a perspective of "efficiently" meeting peoples' needs in the absence of "other" satisfactions.

A concern with this hypothesis is that other satisfactions may be directly exchangeable for recreation needs or opportunities. Unfortunately Ware does not define or describe these "other ways to satisfy peoples' needs." From the viewpoint of the manager of natural resources, resource facilities, or recreation enterprises, demand may indeed diminish during short or long term periods and for diverse reasons. However, this concept relates to resources, resource places or resource conditions, but not in a direct sense to recreation need or opportunity. The professional recreation manager will be quick to point out that need (or expressed demand) for recreation is one matter and user demand for recreation opportunity in a resource setting is quite a different matter. Thus, while management of resources may be a "means to various ends," management (and provision) of recreation opportunity and satisfaction of needs as an end does not necessarily subside coincidentally with peoples' choice of other satisfactions. The importance of recreation has not diminished.

Ware characterizes the role of the recreation resource manager as a client-serving consultant "who helps his client identify and solve recreation resource problems, or who himself acts in proxy to take the decision for his client." This is useful reminder of the manager's client oriented responsibility and the need to adopt an objective, professional service oriented responsibility. At least two omissions seem evident in this characterization, however.

First, as a professional consultant, the recreation manager serves a client "system" which must consider the return or reward objectives of the resource owner or agency, the user community (e.g. the public or a private group), and finally the user himself.

Second, the recreation manager may indeed be much closer to the action and in fact an owner or owner-operator having much more personally internalized objectives relating to management of the resource or a resource-based business. The problem with characterizing the resource manager broadly as a client-serving consultant sidesteps dealing with a host of major problems presently confronting research application. It conveniently excuses the writer from dealing with the large number of managers who do not, in fact, avail themselves of recreation research information. This is an issue confronting researchers, extension specialists and managers, namely, how do we get applicable research information in a useable form to an in-use status by managers. This issue is described finally (and perhaps tardily) in the context of the "Role of Extension Specialists."

The Discussion of the recreation or researcher's role probably provides the reader with the most accurate, comprehensive and useful insight to the researcher member of the researcher-extension specialist-manager "team." Ware clearly challenges researchers to measure their productive worth by how much their efforts increase the efficiency of the manager. He further describes the purposes of research, the ultimate clientele goal of researchers (the resource manager's client), and the difficulty of appropriately functional researcher-manager problem solving. This discourse handily sets the stage for the most important contribution of the paper, an analysis of communication conditions and "barriers" to research application.

From the viewpoint of an extension specialist critiquer I found Ware's approach a candid and lucid depiction of "as things now are" and how some of us at least might "like things to be." I commend this portion of his paper to all members of the recreation professionals team and especially to administrators for a careful and studied reading. Each of us should measure our respective individual and organizational contributions to the closure of the communication gaps as well as to the barriers we help create or augment.

This final section is a sound depiction of many of our fundamental problems. It is a stronger expression of those problems from the research scientists viewpoint than from the viewpoints of the manager or extension specialist, however. For example, little cognizance is offered of the diverse political, economic and social problems which confront the manager and extension specialist on almost a daily basis. It is probably a legitimate supposition that few researchers are aware of these manager and extension education arenas of effort on even a general basis.

Ware's final recommendation, that we search for and test new arrangements different than we now have for sharing responsibility in recreation resources management and research, offers little in the way of concrete step by step procedures. To be sure, he has briefly illustrated the idea of "management by objective" ad hoc problem-solving teams. This may indeed be possible between individuals in many situations and even between individuals of differing agencies, but it seems to require much further consideration to alleviate the barriers throughout the research application organizational system. In any case -- "new arrangements," perhaps as suggested by Crowe, as well as Ware may be the most worthwhile challenge before us.

TOPIC II

NEEDED RESEARCH

ABSTRACTS

DAVEY AND STOUT

Priority Needs in Outdoor Recreation Research.--High priority outdoor recreation tasks are recommended to researchers and research sponsors. These tasks, selected from sixty-five identified by participants at a BOR-sponsored symposium at Harpers Ferry, West Virginia in September 1974, include concern for substitutability among recreation activities, variables affecting participation, land use controls, key elements of recreation attractants, broad behavioral aspects, public reactions to fees and charges, and national energy policies. Several previous efforts are reviewed.

CORDELL

Priorities for Recreation Research in the Southern States.--Deviant behavior, off-road recreation vehicle use and use impacts on developed recreation sites are rated by southern states recreation managers as high priority problem topics for research. Also rated high are coordination and direction of recreation research and effective communication of research results. Although they generally agree with these as research priorities, there are some major differences between researchers' and managers' priorities which point to a communication problem and which need to be resolved.

CERMAK

Wilderness in the East: Problems for Research.--Contrasts between East and West in climate, topography, vegetation and density of settlement give some clues to research needs in wilderness on eastern National Forests. Smaller size of eastern wildernesses and their proximity to settlement may have important effects on volume of use and user satisfaction. The forest may be the most important factor in managing eastern wildernesses. Managers need to be involved in research and researchers should have a role in research applications.

MORE

Urban Forest Recreation: A Strategy for Research.--Recreation pressure on the urban forest is high and is expected to increase. Unfortunately, we know little about this forest or the people who use it. A research program to remedy this will be undertaken in the megalopolitan Northeast. Its goal is to develop a basis of scientific knowledge about recreation in the urban forest.

PRIORITY NEEDS IN OUTDOOR RECREATION RESEARCH

Stuart P. Davey and Neil J. Stout[1]

Abstract.--High priority outdoor recreation research tasks are recommended to researchers and research sponsors. These tasks, selected from sixty-five identified by participants at a BOR-sponsored symposium at Harpers Ferry, West Virginia in September 1974, include concern for substitutability among recreation activities, variables affecting participation, land use controls, key elements of recreation attractants, broad behavioral aspects, public reactions to fees and charges, and national energy policies. Several previous efforts are reviewed.

INTRODUCTION

The continued growth of public recreation programs and activities places stress not only on the basic natural and attracting resources, but also on the land managers and public participants as well. Insufficient knowledge regarding the total interface of these actions and reactions can negate land investments, facility development, and public satisfaction. Facts are needed through research, and the challenge is to identify priority research needs.

Several previous efforts have summarized outdoor recreation research needs. The Bureau of Outdoor Recreation - University of Michigan effort in 1963[2] is recognized as the initial national meeting of multi-disciplinary interests. Here, the groundwork was laid for future efforts along with the full recognition of the tremendous need to understand better the demand, supply, and social factors of the equation.

Regardless of this latter recognition of social import, early work by BOR on the first nationwide outdoor recreation plan found research endeavors had been concerned primarily with resources and slight attention given to the social and psychological aspects. As a result, the Secretary of the Interior asked the National Academy of Sciences to conduct a study and conference to develop a program of recreation research based on evaluation of needs. The conference was held in 1968 and the proceedings[3] delineate the broad discussion and presentations of the resource, social, and economic considerations. This effort was especially valuable in its definitive analysis of recreation service systems. It is obvious, upon review, that the results of this study have never been fully utilized.

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[1] Chief and Assistant Chief, Division of Federal Programs, Bureau of Outdoor Recreation, U.S. Department of the Interior, Washington, D.C.

[2] Proceedings of the National Conference on Outdoor Recreation Research, Co-sponsored by the School of Natural Resources, University of Michigan, and the Bureau of Outdoor Recreation, U.S. Department of the Interior, Ann Arbor, Michigan, May, 1963.

[3] A Program for Outdoor Recreation Research, a report on a study conference conducted June 2-8, 1968, by the NAS for U.S. Department of the Interior. National Academy of Sciences, Washington, D.C. 1969.

The trend at the moment is for regional discussion of research needs. We view this as a healthy situation, and the current efforts by the Forest Service and North Carolina State University are to be commended.

Our effort here is to recognize those priority tasks, as viewed in 1974 by a select group, and then to identify those underlying management problems we view as solvable through the suggested research.

METHODS

On September 4-6, 1974, forty-three scientists, administrators, and practitioners involved with the problems and issues of outdoor recreation met at the National Park Service's Mather Training Center in Harpers Ferry, West Virginia. The Interior Department's Bureau of Outdoor Recreation, in cooperation with the U.S. Forest Service and the National Park Service, called this meeting to assess the state of the art in outdoor recreation and to establish an agenda of current research needs. Based on this assigned missio the participants identified four specific purposes for the Workshop:

1. To identify knowledge-gaps which hinder--or are likely to hinder in the future--the provision of adequated opportunities for the enjoyment of outdoor recreation by the American people;

2. To explore research opportunities--and suggest priorities--for addressing these knowledge-gaps;

3. To identify constraints upon recreation research and opportunities for increasing the effectiveness of recreation research efforts; an

4. To foster adequate commitments of resources, talents, and energies to research applicable to outdoor recreation.

The first session of this three-day workshop heard representatives of agencies and institutions set forth their professional and organizational perspectives on recreation research. Their remarks are recorded in Chapter I of the Proceedings.[4/]

The core session of the workshop occupied the entire second day. Small workgroups undertook to examine knowledge-gaps and research problems in five broad areas of subject interest:

Social and Behavioral Studies
Resource Studies
Administrative and Political Studies
Activities/Facilities Studies
Economic Studies

[4/] Bureau of Outdoor Recreation, Proceedings of the Outdoor Recreation Researc Needs Workshop, Harpers Ferry, West Virginia, Sept. 4-6, 1974.

These workgroup recommendations are presented in Chapter IV of the Proceedings.

The final day's session was occupied with the presentation of the workgroup reports and a general discussion of research strategies. The strategy recommendations are summarized in Chapter V of the Proceedings.

Sixty-five research tasks were derived from the reports of the five workgroups. Time did not permit the assignment of priorities during the Workshop. Therefore, a priority ballot was devised later and distributed to all Workshop participants and certain other recreation professionals, including employees from all relevant organizational units of the Bureau of Outdoor Recreation.

Based on the survey response, 23 research tasks are recommended to researchers and research sponsors as meriting a top priority. They are listed in order of decreasing priority in Table 1. For each task, the table shows the relative priority levels assigned by Workshop participants, BOR respondents, and all respondents taken together. The five right hand columns indicate the areas of research interest (as represented by the five workgroups) which are of primary relevance to each task.

Complete details of the Symposium are available in the Proceedings cited above.

RESULTS

It is the purpose of this paper to present the ten research tasks highly ranked by the symposium participants and the functional, topical headings suggested therein.

Table 1 is self explanatory. Participants ranked number one the need to determine the degrees of substitutability among recreation activities in terms of "psychologically equivalent" experience. Equal ranking was given to the next four tasks to determine as follows:

1. Variables for predicting recreation participation;
2. Key elements of recreation activities which attract participants;
3. Substitutablity among recreation and locales, resources and facilities; and,
4. Effects of design on carrying capacity of certain resources.

Next ranked tasks included the following:

1. Determine standardized approaches to carrying capacity from the biological, physical and sociological aspects;
2. Evaluate various approaches to improving behavior of recreation area visitors;

Table 1. The highest priority research tasks (of 65 recommended tasks) as judged by the 1974 Harpers Ferry Workshop participants and by other respondents to the priority survey--together with suggested research disciplines and approaches

RESEARCH TASKS[1] (In descending order of priority)	PRIORITY RANKINGS			SUGGESTED APPLICABLE RESEARCH DISCIPLINES AND APPROACHES SEE FOOTNOTE[2]				
	PARTICIPANTS	BOR RESPONDENTS	ALL RESPONDENTS	A	B	C	D	E
Determine the degrees of substitutability among recreation activities in terms of "psychologically equivalent" experiences. [illegible]	***		**	X			X	
Identify characteristics of recreation participants--other than the traditional demographic variables--that can be effective in predicting their choices of activities and facilities. (This task is proposed in the recognition that the traditional demographic variables used in most existing recreation research give an incomplete picture of the relevant participant characteristics.) (21)	**	*	***	X			X	
Identify existing and potential means--including pending State and Federal land use control legislation--of establishing and protecting public recreation interests in private land. (32)		***	**		X	X	X	
Determine the key elements or aspects of recreation activities which attract participants. (20)	**	*	**	X	X		X	
Determine the levels of substitutability among recreation locales, resources, and facilities--also in terms of "psychologically equivalent" experiences. (26)	**		*	X	X		X	
Identify the effects of design on the carrying capacity of certain recreation resources particularly in high density use areas. (52)	**		*		X		X	
Establish standardized approaches for determining biological, physical, and sociological carrying capacities of recreation resources for specific activities and specific types of environments. (50)	*	**	**	X	X		X	
Develop guidelines for enhancing recreation opportunities in the course of non-recreation land development and management activities. (such as in Task 56 below) (57)		**			X	X	X	X
Evaluate alternative approaches to minimizing conflict and securing cooperation among public agencies and also between the public and private sectors in the provision of recreation areas and services. (44)		**		X			X	
Evaluate the effects on public recreation programs of existing and potential legislative enactments related to sources of funding. (36)		**				X		X
Evaluate various approaches to improving behavior of recreation area visitors such as restrictions, penalties education, interpretation, and modifications in planning and facility design. (49)	*		*	X		X	X	
Identify and evaluate the relationship of recreational and leisure pursuits with other life domains--such as job and family--in terms of systems, processes, outputs, benefits, and meanings. (60)	*	*	*	X			X	
Develop techniques for predicting changes in recreation consumption patterns associated with major shifts in variables affecting how Americans live. (3)	*	*	*	X				X
Ascertain those components of recreation activities and/or facilities that seem to be valuable in terms of enhancing participants' self-realization, self-actualization, and self-image. (30)	*		*	X			X	
Develop and evaluate means of minimizing the adverse effects on recreation opportunities of non-recreational activities such as timber-cutting, drainage, irrigation, energy development, channelization, dredging and filling, urbanization, industrial operations, mining, and highway building. (56)	*	*	*		X	X	X	X
Identify and evaluate the factors involved in non-participation and anti-recreation behavior. (29)	*	*	*	X			X	
Determine the dynamic properties of recreation activities, facilities, and service systems that can influence changes in recreational tastes over time (cultural, psychological, sociological, etc.) (22)	*		*	X			X	
Determine the relative resiliencies of certain ecological systems if recreational carrying capacities are exceeded; and develop techniques for improving such resiliencies. (51)	*				X		X	
Analyze the effects of environmental education and interpretation on the quality of recreation experiences. (54)	*			X	X		X	
Evaluate the effects on outdoor recreation opportunities of political considerations such as energy policy, environmental protection, and highway construction. (47)		*	*		X	X		
Identify the relationship between public fee structures and the supply of competing and complementary private facilities and services. (12)		*				X		X
Analyze the effectiveness, benefits and costs of the use of recreation services to reduce deviant behavior and ameliorate social problems. (14)		*		X			X	
Identify and evaluate those public and private property aspects of land and resources which are relevant to outdoor recreation. (31)		*			X	X	X	

*** Highest priority task--out of 65 recommended research tasks--as identified, respectively, by Harpers Ferry Workshop participants, BOR respondents to the priority survey, and all survey respondents taken together. (Ranking criteria are described in Appendix A.)

** Next 4 tasks in descending order of priority as identified by each of the above groups of respondents.

* Next 15 tasks in descending order as above.

[1] The number in parentheses following each research task description is the sequence number of that task as listed in the priority ballot. See Appendix A.

[2] Suggested applicable research disciplines and approaches as represented by the five workgroups:

A. Social and behavioral studies
B. Resource studies
C. Political and administrative studies
D. Activities/facilities studies
E. Economic studies

3. Evaluate relationships of leisure pursuits to other life domains;

4. Find techniques to predict changes in recreation patterns associated with major shifts in variables affecting life style; and,

5. Ascertain components of recreation activities valuable to participant self development.

The rest of the 23 relate to lower ranked tasks, but still are of importance in the areas of non-participation/anti-recreation behavioral aspects of recreation and all of its implications for management maintained a high profile, and need for research. Governmental agencies, as you probably are aware, are wary of behavioral research, especially when applied to the users of their facilities.

We view the results of the symposium and the analysis of the priority tasks identified by participants and subsequent reviewers in the following terms and needs for research, in behalf of managers of public, and probably private, recreation enterprise:

First, the "why" and the "substitutability" of participant action, resource attraction and general behavioral aspects are of great importance to understand better the recreation phenomenon. Much remains to be accomplished here.

Second, while the "resource capacities" are increasingly clear, the sociological/psychological capacities are not. Here again, much remains to be accomplished. We are pleased to report that BOR is funding during this fiscal year some research on carrying capacities, including the human aspects thereof.

Third, our ability to predict demand within an understanding of the rapidly changing lifestyles around us are sorely lacking. Of great importance is the rapidly changing energy scene. The "who" is going to do "what" question remains a challenge. In FY 1975, BOR funded a National Academy of Sciences study of the whole demand question. That report is expected soon.

Fourth, the whole thrust of recreation development needs early analysis, if for no other reason than to answer the increasingly common complaint that "operation and maintenance funds are unavailable," therefore, no area, no facilities. The thrust of Federal properties and programs upon lower levels of government might or might not accelerate such reactions--or a surplus of facilities may, in fact, exist in many areas. On the other hand, the American expectation of "free" public recreation could dictate the financial inabilities of agencies to provide opportunities beyond a given level. Facts here are needed as soon as possible. Again, we are pleased to report that the BOR is funding this fiscal year an analysis of public reaction to public agency recovery of operation and maintenance costs for recreation facilities.

DISCUSSION

The sponsors recognize that the Harpers Ferry Workshop was held under certain significant limitations. Essentially one working day was available to the conferees. The participants' backgrounds did not cover the full spectrum of recreation practitioners and scholars. A good start was made on identifying research needs, but it will be essential to establish linkages to other professional interests in the future.

The Harpers Ferry Workshop stressed the "people" aspects of outdoor recreation. Behavioral science approaches to recreation problems received more emphasis than the traditional economic approaches. Special emphasis was given to the meaning of recreation experiences to the participant--the benefits he seeks and the results he actually achieves. Those present felt that the complex of man-environment interactions called outdoor recreation must be understood much more deeply and comprehensively if Americans are to have a full range of opportunities to enjoy the outdoors.

The Workshop participants and the survey respondents were not representative of all areas of interest in outdoor recreation. Urban and commercial recreation interests--as well as the health and design professions--were underrepresented. It should be noted, however, that the proposed research tasks focus on underlying principles and relationships. Results of this research would apply to a broad spectrum of outdoor recreation situations, locations, and activities. The participants deliberately avoided dealing with specific recreation activities such as swimming, bicycling, or off-road vehicle use.

CONCLUSION

Our conclusion is that the Harpers Ferry Workshop was a useful method to update outdoor recreation research needs. Further, the proceedings of the meeting can serve as the vehicle to a greatly expanded audience whose concern and interest can assure needed solution to many problems. The priority items listed in Table 1 can be used or amended for numerous specific research tasks. The several research projects contracted recently by our own organization stand as examples.

More important, we believe, are the functional areas identified for research to assist both the research and recreation manager both to understand and manage better the recreationist and the opportunities he seeks.

PRIORITIES FOR RECREATION RESEARCH IN THE SOUTHERN STATES

Harold K. Cordell[1]

Abstract.--Deviant behavior, off-road recreation vehicle use and use impacts on developed recreation sites are rated by southern states recreation managers as high priority problem topics for research. Also rated high are coordination and direction of recreation research and effective communication of research results. Although they generally agree with these as research priorities, there are some major differences between researchers' and managers' priorities which point to a communication problem and which need to be resolved.

Additional keywords: Research priority, recreation research, recreation problem identification, research communications.

One of the most frequently voiced complaints about research is that it is not addressing the problems of highest priority. Managers and planners often feel that their informational needs are being ignored. The 1974 National Outdoor Recreation Research Needs Workshop was one effort to overcome this shortcoming of research. Another effort which addressed the Southern States specifically was conducted by the Southern Regional Task Force on Research Needs in Recreation, Aesthetics and Other Landscape Values.

The basic philosophy under which the Task Force operated was one of making sure that the most important issues or problem areas had first been identified and rated before any attempt was made to list studies needed to address these problems. Focusing first on "needed" studies instead of identifying high priority problems seems to be a common error of many previous efforts to identify research needs. The basic pitfall of this approach is that the problem, the underlying reason, for doing research in the first place very often never becomes evident. As a result we are never sure that the highest priority problems are being addressed and the complaint that research needs to be more relevant is reinforced.

The Task Force was composed of a multidisciplinary team including an economist, a sociologist, an extension and planning specialist, a forester, an ecologist, and a psychologist. The procedure was to identify the more important problem areas in recreation management and planning and to obtain a priority ranking of these problems by asking researchers and practitioners in the 13 Southern States to vote on the importance of each.

Twenty-one different problem areas were identified by the Task Force after considerable input from a selected panel of managers and planners. The final list of problems along with a written description of each problem situation was sent to recreation practitioners and researchers throughout the Southern States. Persons receiving this material were asked to rate each problem independently by assigning a scale value from 1 (most important) to 5 (least important). A total of 186 practitioners and 40 scientists responded representing a wide range of private, federal, state and local concerns. A similar assessment of these 21 problem areas was obtained from participants in this Workshop.

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PRIORITY PROBLEMS FOR RESEARCH

In table 1 titles of the 10 highest priority problems are listed. These are ordered according to the 1974 voting by practitioners only. The criterion for ordering was the percentage of respondents which ranked a problem as number 1 or number 2 in importance on a scale ranging from 1 to 5. Also shown is the voting on these same problems by the practitioners attending this 1975 Workshop. All who indicated they would be attending were sent a ballot and problem descriptions identical to those mailed to Southern States practitioners in 1974.

There were some substantial differences in the ranking of the 21 problems between this Workshop group and the respondents to the 1974 survey. Some of this is the result of the Workshop group's being less representative of the total range of southern recreation management interests. Some of this difference may also be due to increased awareness of problem situations.

The top 3 problems identified by Workshop attendees were:

1. Physical and biological impacts of recreation use on developed sites (74 percent voted 1 or 2)
2. Littering, theft, vandalism and other deviant behavior in recreation areas (73 percent)
3. Coordination and direction of southern recreation research (65 percent).

These 3 problems were among the top 5 as ranked by the 1974 survey respondents and indicates a degree of general agreement between the two groups. This also reinforces the 1974 finding that research dealing with developed recreation sites and management problems associated with the recreational use of these sites is still very much in demand. Researchers and funding sources have been strongly deemphasizing this direction for research in recent years.

Use of wild lands or other areas by off-road recreation vehicles was also rated relatively high by the Workshop attendees (no. 6 overall, 56 percent ranked it 1 or 2) and it was rated especially high by the 1974 group (no. 2, 82 percent). The obvious resource impacts, conflicts with other recreationists, and large numbers of participants are likely reasons for this outcome.

A major difference between the Workshop group and the 1974 survey respondents was the ranking of two problem areas as highly important for research attention:

1. Communication of recreation research results (65 percent of Workshop group, ranked no. 4)

Table 1.--Ten highest-priority problems ranked by southern states practitioners and percentages rating each problem 1 or 2

Problem Title	Percentage of practitioners who rated problem 1 or 2 1974	Percentage of practitioners who rated problem 1 or 2 1975	Rank order by 1975 respondents[a]
Littering, theft, vandalism and other deviant behavior in recreation areas	85	73	2
Use of wild lands or other areas by off-road recreation vehicles	82	56	6
Physical and biological impacts of recreation use on developed sites	82	74	1
Evaluation of recreational benefits from urban forest and open space resources	64	39	15
Coordination and direction of southern recreation research	63	65	3
Interpretation and understanding of forest and natural environments	62	47	10
Methodology of recreation research	59	48	9
Benefit/cost analysis of recreation alternatives	56	43	14
Providing recreation opportunities for the aged and handicapped	54	21	21
Inadequate data bases and methods for comprehensive recreation planning	50	47	12

[a] Indicates relative ranking from the original list of 21 problems.

2. Evaluation of environmental impacts resulting from recreation use and development (61 percent, ranked no.5).

These two problem areas received much lower ranking in 1974 (ranked no. 10 and no. 13 by the 1974 group).

Particularly notable in the voting of the Workshop group is the ranked importance of having well coordinated research directed toward the most relevant problems (ranked no. 3) and, as indicated above, of adequately and clearly communicating the results of research so that it can be understood (ranked no. 4). These problem areas, of course, are primarily the reason for attending this Workshop.

DIFFERENCES BETWEEN MANAGERS AND RESEARCHERS

It is evident from the 1974 survey and from the survey of Workshop attendees that coordination and communication between researchers and practitioners strongly need to be improved. Dick Cottrell, Dennis Crowe, and Ken Ware addressed some of the problems associated with getting a more smoothly operating working relationship and better communication between researchers, extension specialists and practitioners. They also discussed some of the possible actions that could be taken to achieve improvements.

The need for better communication was vividly pointed up by comparing the ranking of problems by practitioners and scientists attending this workshop. While practitioners are more concerned with the impact of the recreationist on the site and with other day-to-day management problems, we scientists appear more concerned with broader social issues and with theoretically related questions. The six top ranked problems by scientists included:

1. Use of recreation and aesthetic preferences in the development of resource management and utilization policies (77 percent)
2. Use of phychological needs data for recreation resource decisions (77 percent)
3. Evaluation of recreational benefits from urban forest and open space resources (77 percent)
4. Effects of public and private recreational developments on social change and life-styles of local communities (66 percent)
5. Control of littering, theft, vandalism and other deviant behavior (66 percent)
6. Coordination and direction of recreation research (55 percent).

The voting by both practitioners and scientists indicates the importance of deviant behavior and research coordination problems. But disagreement concerning other top priority problems indicates a real need for more communication between those of us attending this Workshop. The 4 problems ranked highest by managers and planners were ranked 9, 5, 6, and 11 by the researchers who are here.

SUMMARY AND DISCUSSION

It appears that we are able to identify important problems to which research should be applied. But there is some disagreement concerning which problems are most important. Managers, planners and administrators are more concerned with problems with which they must deal every day. Researchers appear to be concerned with more basic questions and with theory building. Yet the clientele of the researcher is the manager. Does this indicate that the direction which research takes should be dictated by the manager? But if this happens, what will become of basic research which has its value in addressing questions that have more general or long-range consequences?

WILDERNESS IN THE EAST: PROBLEMS FOR RESEARCH

Robert W. Cermak[1]

Abstract.--Contrasts between East and West in climate, topography, vegetation and density of settlement give some clues to research needs in wilderness on eastern National Forests. Smaller size of eastern wildernesses and their proximity to settlement may have important effects on volume of use and user satisfaction. The forest may be the most important factor in managing eastern wildernesses. Managers need to be involved in research and researchers should have a role in research applications.

Additional keywords: Contrast in size and scale, alternatives, carrying capacity, vegetative influences on resiliency, individualized definition of wilderness.

For a resource manager born in the West and raised on western resource problems, the East is a startling contrast. The most striking aspects of eastern North America, as we drove from Pueblo, Colorado to the Shenandoah Valley of Virginia in August 1972, were the abundance of green vegetation and the presence of homes, communities and small towns throughout the land.

The land was softer, more receptive than the sagebrush flats of Wyoming and South Dakota; the barren peaks of the Rockies; the alkali plains of the Great Basin; or the sunbaked foothills of the Sierra Nevada.

We saw mountains; they were sometimes imposing, but they had rounded summit and were entirely covered with trees. In fact, trees were everywhere - between houses and towns, in plantations, alongside cornfields and far off into the distance. For someone who had traveled many miles in the West and seen only scraggly windbreaks or a few cottonwoods, it was refreshing.

There were houses, farms and small communities within sight almost constantly. We couldn't help but contrast the scene with the long, lonely trip through Wyoming's Thunder Basin; our drives across Nevada, nearly empty of peopl and places; or the sparsely settled high deserts and mountains of eastern Oregon

If you are worried that this is a travelogue and not a paper on eastern wilderness problems, let me reassure you at this point. I began this way becaus there are great contrasts in East and West and these few paragraphs have illustrated some of them. These are some of the contrasts we need to consider when discussing research needs in wilderness on eastern National Forests.

These contrasts are important because designated wilderness is new to eastern National Forests. If we exclude the Boundary Waters Canoe Area as a special and unique situation, there were only three small designated National Forest Wildernesses in the East before the Eastern Wilderness Act was signed on January 1975. This new management situation appears to call for new research. Application of knowledge learned in western wilderness without modification to the East could lead to more problems than it solves.

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The West is an expansive, wide open country, full of long vistas. Scale is magnified and scenery can be almost overpowering. On the other hand, the East has lower relief, is dominated and softened by forest and other growth. Climatic conditions and the dense forest often restrict views to the close-in, the smaller scale of trees, streams, wildlife and flowers.

The contrast in scale is matched by a contrast in size between eastern and western wilderness. Averages can be deceiving but they illustrate this point well enough. As of December 31, 1974, the average size of 66 western National Forest wildernesses was 160,943 acres while the average of 18 eastern National Forest wildernesses is 12,602 acres (excluding Boundary Waters Canoe Area). Only four eastern wildernesses are over 20,000 acres in size.

What effect does size have on use and management of eastern wilderness? Will carrying capacity be subject to the same limitations as in western wilderness? In view of the small size, how should surrounding lands be managed?

The answers to these questions may depend upon the reasons why people visit eastern wilderness.

Typically, western wilderness supports most of its use in narrow bands along lakes and streams with trail access. However, even this use is not equally distributed. Stankey (1973) reported on three western wildernesses where use was concentrated at a few of the most attractive fishing areas, lakes and streams and near access points.

Eastern wilderness often lacks outstanding fishing, lakes and large streams; cross-country travel is limited by the heavy forest growth. What will bring visitors other than a desire for solitude? It might be the desire to hike the wilderness trails. Hiking has a long tradition in the East and backpacking is growing rapidly in popularity.

If hiking and backpacking in a forested atmosphere are major reasons for using eastern wilderness, then a new look at trail routes and the density of trails would be needed. The thick forest in most eastern wildernesses would permit more trails per acre and more use, provided overnight camping space were available.

Under these circumstances, size may be less important as a factor in meeting eastern wilderness needs. Perhaps state and local government could also play a larger role in supplying designated wildernesses. Industry's "pocket" wilderness could become another alternative. How small can a designated wilderness be in the East and still provide a wilderness experience?

One of the contrasts I mentioned earlier had to do with the density of settlement in the East versus the West. It is not uncommon to find houses, farms, towns and highways adjacent to eastern wildernesses or to have cities within a few miles. It is difficult to say what effect the proximity of settlement will have on user satisfaction. It may not be as important as it first appears because thick cover masks sight and sound, even when it is only a mile distant or less.

The forest seems to me to be the key element in eastern wilderness. Perhaps this is appropriate for the term "wilderness" originally referred to the forest and its wildlife (Nash 1967). The eastern forest is not tame as anyone can attest who has struggled through a laurel thicket on a cloudy day. In fact, parts of some designated eastern wildernesses and some study areas are downright dangerous to be in because of wildlife or terrain features. Eastern forests aggressively take over old fields or openings with a growth so thick that it can become oppressive. The demand for eastern wilderness arose partly because of the eastern forests' ability to heal its wounds quickly; what once had been cutover woods became wilderness forty years later.

Forests are so wide spread over the East that they may affect the attitude of people in the East toward wilderness. Many easterners think the wilderness is at their back door. They can visit the woodlot or go over the fence to the paper company or lumber company's land. Or the National, State or township forest is near at hand. In a few steps they are swallowed up by the forest.

"When we walk, we naturally go to the fields and woods.....," Henry Thoreau said in his famous essay, Walking, "My vicinity affords many good walks; and although for so many years I have walked almost everyday, and sometimes for severa days together, I have not yet exhausted them." (Duncan 1972) To be sure, he also complains about the building of houses and cutting down of the forest but when visiting Concord, Massachusetts two years ago, I was interested to find most of the country nearby is still wooded.

Several writers have said that wilderness is found along a spectrum from the most civilized place to the least. Carhart (1961), Spurr (1966), and Nash (1967), for example have all suggested that the definition of wilderness is so highly personal that it means something different to each of us. A logical expression of this idea is, as they propose, a scale or spectrum of situations varying from the least wild to the most wild.

If the forest is a major element in what most of us think of as wilderness, then the easterner has a distinct advantage over his western counterpart. In the East, the forest is almost everywhere except in the urban areas and the cultivated farmlands. It offers easy escape from the sights and sounds of civilization. But the East also has many more people than the West.

Managers of eastern wilderness need to know how to keep these small areas from being overrun by visitors from the massive population centers of the East. Are there different attitudes toward wilderness in the East? What are the alternatives to legislated wilderness in the East?

Lloyd and Fischer (1972) describe a continuum of recreational opportunities and point out the need for "more, and a wider variety of, dispersed recreation opportunities outside designated wilderness." I agree, but believe this approach is only half of the solution. We need to actually deemphasize visitation to designated wilderness while we emphasize the opportunities elsewhere. Many wilderness visitors seem to think they will have a blinding flash of "wilderness experience" when in the confines of a designated wilderness. I think the wilderness spectrum of Nash, Spurr and others largely coincides ith the recreation opportunity continuum described by Lloyd and Fischer. ost people can find their personal wilderness experience outside designated ilderness and often it can be a higher quality experience. Certainly we eed to encourage them to do so if we are to avoid overuse of eastern wilderess within a few years after their designation.

Protection of wilderness from human overuse is the greatest concern n many western wilderness. Insect and disease attacks usually are allowed o run their course; and in predetermined portions of some wilderess, wildfires are allowed to "burn themselves out."

We need research to determine the potential effects of insect, disease nd fire on the small wilderness of the East. Can we afford to allow wildire, oak wilt, southern pine beetle, gypsy moth and similar threats to he forest to "burn themselves out?" With large areas of forest gone from he eastern wilderness, would the wilderness experience remain?

A brief review of the contrasts between East and West has brought ut some problems for research to consider. Summarized they are as follows:

1. What effects will small size have on use and management of eastern wilderness? Can size be even smaller? If so, do state and local government and industry have a role in supplying wilderness?

2. What should be the carrying capacity of eastern wilderness?

3. What effects do the small size of eastern wilderness have on the management of surrounding lands?

4. What is the public concept of eastern wilderness?

5. What are the reasons besides a search for solitude that people visit eastern wilderness?

6. How does dense forest growth help or hinder management of eastern wilderness?

7. How can we emphasize the use of non-wilderness and deemphasize the use of designated wilderness?

8. What are the potential effects of serious outbreaks of fire, insects or disease on the wilderness experience in eastern wilderness?

I am sure there must be many more problems associated with management eastern wilderness but it is appropriate at this point to say a few words out solving problems.

In a new venture such as managing eastern wilderness, we need the benefit all that has been learned elsewhere about wilderness management. We need w knowledge because, as outlined above, the eastern situation is different.

Making the most of research capabilities requires cooperation between manager and researcher.

I would not be the first to say that cooperation between researchers and managers has not been effective. It is too often true. This is sad because both are losers. New knowledge could save the manager time and money and produce a better service or product. And for the researcher, the real payoff is not the paper he produces but the effect of that paper on management methods and attitudes.

It is pretty well agreed in management theory that the involved worker will be more interested in the quality and quantity of the product. The manager should have a stake in the research if he is to be committed to it and the researcher should be involved in the application of research results if progress is to be made.

Douglas MacGregor (1967) says, "Identification and commitment rest on linking the individual's own goals with those of the organization." If the manager and researcher can agree on the goals they seek and keep in contact during the management and research process, then they are both more likely to be successful. In my opinion, the manager must assume the larger burden and go more than halfway in providing the climate that makes for effective research, and also effective application of research results and the feedback the researcher needs.

In closing, I would like to say a few words about the realities of wilderness management on National Forests of the East. Wilderness management does not exist in a vacuum. It must be accomplished by men who have many other demands on their time and who face an increasing workload with a stable or declining budget. Typically they will react to the heaviest pressures first and wilderness use usually generates comparatively light pressure.

Managers must have priorities and wilderness management must fit into that priority system. What really counts are the results on-the-ground. Too often research and even policy have been frustrated by the use of ineffective methods for transforming them into action. It behooves us all to look at what is really happening on-the-ground if we are to be successful in improving management and research.

LITERATURE CITED

Carhart, A. H. 1961. Planning for America's Wildlands. Nat. Audubon Soc., Nat. Parks Assn., Wilderness Soc., Wildlife Mgt. Inst. 97 p. Harrisburg, Pa., The Telegraph Press.

Duncan, J. L. ed. 1972. Thoreau: The major essays. 303 p. N. Y. : E. P. Dutton Co., Inc.

Lloyd, R. D., and Fischer, V. L. 1972. Dispersed versus concentrated recreation as forest policy. 16 p. 7th World Forestry Congress, Buenos Aires, Argentina

MacGregor, D. 1967. The professional manager. 202 p. N. Y.: McGraw Hill, Inc.

Nash, R. 1967. Wilderness and the American mind. 256 p. New Haven: Yale Univ. Press.

Spurr, S. J. 1966. Wilderness management. VI. H. M. Albright Conservation Lectureship, Univ. of Calif., School of Forestry, Berkeley.

Stankey, G. H. 1973. Visitor perception of wilderness recreation carrying capacity USDA For. Serv. Res. Pap. INT-142, 61 p., illus. Intermt. Forest and Range Exp. Sta., Ogden, Utah.

A CRITIQUE OF THE PAPER ENTITLED "WILDERNESS IN THE EAST: PROBLEMS FOR RESEARCH"

R. Duane Lloyd[1]

Robert W. Cermak has posed eight questions about eastern wilderness management that he recommends for research. In general I agree, but I want to build on his case further and offer some additional perspectives.

The eight questions have been developed from a background of contrasts between western and eastern wilderness resource conditions such as forest types, density of vegetation, typical scale scenery, screening of sights and sounds by vegetation, proximity to population centers, and typical size of wilderness areas. Recognizing differences between the East and West is important, but there also are some similarities that need to be recognized, too.

Much of our best wilderness research has been quite fundamental. For example, the basic patterns of interactions by visitors with the wilderness environment and with one another (Frissell and Stankey 1973) are the same in the Boundary Waters Canoe Area (BWCA) and in the West. Also, independent research in the two ends of the country indicates that hikers, their preferences, and their behaviors are essentially the same in both West and East (Hendee _et_ _al_. 1968, Murray 1974).

Where research has developed basic principles, they should be applicable in both the East and the West. It should not be necessary to do eastern wilderness research that will "reinvent" things already learned in the BWCA and the West. This is particularly true for research on people who visit wilderness and seek dispersed types of recreational opportunities.

At the same time, Cermak is correct in telling us that the _resource_ differences are important and that we will need to modify western management practices for use in the East. Pilot testing, further development, and modification will be needed. This can come best through teamwork by research scientists and resource managers.

In the West, Forest Service research has given more attention to wilderness visitors than to the resources. I see a need, in the East, to give considerable priority to studies of the resources and visitors' impacts on them.

It may be that the denser vegetation in eastern wildernesses will permit higher visitor-carrying capacities than in the West. At any rate we expect heavier rates of visitation because of the proximity of large numbers of people. Impacts of visitors on the land, water, and vegetation are a high-priority wilderness and backcountry management problem. The North Central Forest Experiment Station, in cooperation with the Superior National Forest and the University of Minnesota, has done some research of this kind in the BWCA. The Northeastern Forest Experiment Station has started work of this kind in New England, in cooperation with the National Forests, the Appalachian Mountain Club, and several universities.

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Ecological succession proceeds more rapidly in the East than in most of the West. Thus it is important that we face the problems of biological management of wilderness. To many people the phrase "management of wilderness" is unacceptable; they seem to assume that man can pickle and preserve dynamic ecological systems. Research has shown that total protection can cause unnatural biological results (Heinselman 1973). The potentially undesirable results of management for protection only will become evident much sooner in the East than in the West.

I join Cermak in a plea that wilderness research be conducted with a broad perspective that will require examination of wilderness-management problems within a larger context. The key to wilderness management may lie in nearby non-wilderness. We also need to remember, and help the public understand, that wilderness has not been established for recreational purposes alone. The Wilderness Act has dual objectives, which I paraphrase as (1) nature preservation and (2) primitive recreation. We need to do the research and development that will help bring to pass a balanced spectrum (or continuum) of forest-based recreational opportunities so that we can, as Cermak urges, "...deemphasize visitation to designated wilderness while we emphasize the opportunities elsewhere."

Wilderness research began in the BWCA and has made substantial progress in the Northern Rocky Mountains, the Pacific Northwest, and most recently in California. Significant research contributions have been made in less than 10 years, with a modest budget and a small team of scientists. A number of research findings have been integrated into wilderness-management policy and plans. Examples include the uniform wilderness permit, segregating or zoning uses--based on different preferences and styles of travel, size-of-party limitations in the BWCA and some other places--and the coming use of the new wilderness travel simulator. The simulator is a good example of Research-National Forest System (NFS) teamwork. The idea began with research scientists; the final product (now being handed over to NFS wilderness managers) was polished through a joint NFS-Research pilot-test and development effort.

We have able and aggressive resource managers who are dedicated to the wilderness concept. We have a national team of capable and creative research scientists. Experience over the past 10 years shows that we can do outstanding research and work as a team to apply it. I am confident that we can and will (1) adapt basic principles to eastern conditions, (2) solve wilderness problems unique to the East, and (3) apply the results.

Literature Cited

Frissell, Sidney S., Jr., and George H. Stankey. 1973. Wilderness environmental quality: search for social and ecological harmony. Soc. Am. For. Annu. Meet. Proc. 1972: 170-183, illus.

Heinselman, Miron L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quat. Res. 3(3): 329-382, illus.

Hendee, John C., William R. Catton, Larry D. Marlow, and Frank C. Brockman. 1968. Wilderness users in the Pacific Northwest: their characteristics, values, and management preferences. USDA For. Serv. Res. Pap. PNW-61. 92 p., illus. Pacific Northwest For. and Range Exp. Stn., Portland, Oreg.

Murray, Judith Buckley. 1974. Appalachian Trail users in the southern National Forests: Their characteristics, attitudes, and management preferences. USDA For. Serv. Res. Pap. SE-116. 19 p., illus. Southeast. For. Exp. Stn., Asheville, N. C.

Stankey, George H. 1973. Visitor perception of wilderness recreation carrying capacity. USDA For. Serv. Res. Pap. INT-142. 61 p., illus. Intermountain For. and Range Exp. Stn., Ogden, Utah.

URBAN FOREST RECREATION: A STRATEGY FOR RESEARCH

Thomas A. More[1]

Abstract.--Recreation pressure on the urban forest is high and is expected to increase. Unfortunately, we know little about this forest or the people who use it. A research program to remedy this will be undertaken in the megalopolitan Northeast. Its goal is to develop a basis of scientific knowledge about recreation in the urban forest.

Additional keywords: Urban parks, recreation behavior.

Every day, millions of Americans use city parks and forests for recreation. Despite the obvious importance of these areas, most of our recreation research has been focused on wilderness and other remote areas. Few studies have dealt directly with recreation in the urban forest. In this paper, my purpose is to describe and explain a program of research on urban forest recreation that I am developing with other scientists in the USDA Forest Service's Pinchot Institute for Environmental Forestry Research.

THE PROBLEM

By the year 2000, if current trends continue, the vast majority of our population will be concentrated in large metropolitan areas. Access to the forest for recreation will be limited. Some people will, of course, have the money to visit any forest anywhere, but for most people the neighborhood will continue to be the dominant living space. Their principal contact with forests will probably be in public parks and on occasional trips to the fringes of the metropolitan areas. This forest, with buildings, fields, houses, roads, fences, and private holdings interspersed, is the urban forest.

The pressure on the urban forest for recreation is high, and a number of trends indicate that it will continue to increase. First, most Americans have more leisure than ever before, because of decreases in the workweek (Zeisel 1958) and in the length of working life (Wolfbein 1954). In addition, experts have predicted that a 4-day, 34-hour workweek will be the average by 1985 (Shafer, Moeller, and Getty 1974).

Yet, it is not the total quantity of leisure that is important to recreation, but rather its distribution. Much of the total amount of leisure is found in time off after work or school, or on weekends--times when there is little chance to make major trips into our more remote forests. The result is that people who want to visit the forest during these times visit the urban forest--the one close to home.

Other factors augment the importance of the urban forest in satisfying the recreational needs of Americans. First, the country is currently experiencing a severe recession. Many people are unemployed and many others are concerned about keeping their jobs. People today are worried about money. As a result, major trips and vacations are being put off in favor of shorter trips closer to home. This implies a greater demand for recreation in the urban forest.

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Second, the current shortage of energy supplies, with rapidly rising gasoline prices, gasless Sundays, and especially the uncertainty about adequate gasoline supplies, has probably caused many people to stay closer to home, visiting the urban forest rather than its more remote counterpart.

Despite the fact that so much recreation occurs in the urban forest, this is precisely the forest that we know the least about. Much of our research has been aimed at understanding the wilderness user or the visitor to developed campgrounds in remote forests. It should come as no surprise that almost all our studies find us dealing with highly educated, white, upper middle class people. By focusing so much of our attention on these people and these areas we are overlooking millions of other people who use the forest--the urban forest. We are also neglecting millions of potential consumers of our services who might visit the forest if they had the opportunity to do so.

Here, then is the crux of the problem: there are millions of consumers and potential consumers of urban forest recreation in our nation's cities about whom we know little or nothing. We need a research program to develop a base of scientific information both about these people and about the recreation resources of the urban forest so that we can facilitate the delivery of forest recreation services to the largest segment of our population--the people of our nation's cities.

THE GEOGRAPHICAL AREA OF CONCERN

What is meant by the urban forest? A USDI (1974) definition of an urban recreation complex may help. They began by including counties that were within 120 miles of a central city with 500,000 or more population. This area is then divided into two zones--a day-use zone from 0 to 40 miles, and an overnight-use zone from 41 to 120 miles. The inner zone is assumed to be within 1 hour's travel of the city, while the outer zone requires more extended trips of 2 to 3 hours.

There are 58 of these urban recreation complexes throughout the United States. While I hope that our research findings will be applicable to recreation management around all the nation's cities, the primary focus of our research will be in the megalopolitan areas of the Northeast.

Megalopolis consists of a series of metropolitan centers from Boston, Massachusetts, to Washington, D.C., surrounded by rural areas that supply resource services such as water, food, and recreation. This service area (5 percent of the nation's land) extends from Canada to North Carolina, between the Appalachians and the Atlantic, and contains 26 percent of the nation's population (Gottman 1961).

Pronounced changes from rural to urban land uses are occurring within this area, and a shift of 8,755,000 acres to urban use is expected between 1960 and 2020. The area's population has increased from 34.4 million in 1940 to 50 million in 1970. It is expected to reach 55.6 million by 1980, 69.5 million by 2000, and 86.2 million by 2020 (USDA 1970).

Marked changes in the distribution of land uses are expected in the North Atlantic Region between 1963 and 2020: decreases in cropland (from 15.2 to 6.0 percent) and pasture (6.3 to 2.6 percent), and increases in forest land (57.4 to 64.4 percent) and urbanized areas (6.0 to 14.3 percent) (USDA 1970).

TOPICS FOR RESEARCH

Considering the nature of the problem, we felt that a logical approach was to ask these questions: What areas and activities are available to urban people for recreation? What do people actually do in these areas? What do urban forest recreation areas mean to their users? What benefits are provided by urban forest recreation areas? And how do people choose one area or activity from an array of alternatives? Each of these questions translates loosely into a general topic for research, and each is discussed more fully below.

I. Supply characteristics of recreation in the urban forest (i.e., what areas and activities are available)

This research topic has received fairly extensive treatment in the literature. For example, the USDI (1974) found that the Northeast (including New England, New York, New Jersey, and Pennsylvania) is over 90 percent rural (non-city) and contains 100 million acres of open fields, marshlands, and woodlots. Yet the Northeast ranks last in recreation acreage per capita, with 0.2 acre. State-owned areas make up most of this acreage (table 1).

Table 1.--Recreation areas in the Northeast in public ownership

Type of government	Area
	(millions of acres)
Federal	1.9
State	7.9
County	0.1
Municipal	0.2
Total	10.1

Recreation land is even more scarce for residents of metropolitan areas: only 0.04 acres per capita in the Northeast (USDI 1974). The supply of specific types of facilities is shown in table 2.

This and similar surveys of metropolitan areas (e.g. National Recreation and Park Association 1974) have given us adequate knowledge of the recreational opportunities in and around our nation's major cities, both in the Northeast and in other regions of the country. But there is a related topic which has not received much research attention and upon which we will focus our research effort: the public's perception of the facilities available to it.

Table 2.--Recreation facilities in the Northeast (from USDI 1974: 109)

Facility	Within 40 miles of central city				Within 41-120 miles of central city			
	Public		Private		Public		Private	
	Acres	Units[a]	Acres	Units	Acres	Units	Acres	Units
Swimming facilities								
Pools	15	73	364	239	19	70	532	262
Beaches	5,110	832	4,565	768	1,002	546	4,205	1,554
Trails								
Foot	971	1,275	3,562	4,675	2,949	3,927	6,075	7,973
Bicycle	275	336	152	200	--	--	504	661
Horseback riding	288	298	1,879	1,942	304	314	2,494	2,577
Campgrounds								
Tent camp	2,094	12,478	12,087	42,504	6,004	24,577	12,122	43,696
Trailer camp	200	723	3,593	32,916	215	2,549	5,726	49,102
Group camps (capacity)	1,122	74,138	12,227	31,066	1,076	112,973	13,838	38,165
Picnic sites	15,627	89,393	30,858	78,427	6,928	106,806	31,585	78,950
Playfields	41,270	511	14,636	3,571	2,867	605	12,008	2,578
Winter sport sites								
Ski sites	965	80	8,206	320	2,756	174	2,092	126
Ice skating sites	3,220	585	4,768	715	4,304	396	12,391	704
Golf courses	12,002	25	90,083	1,112	2,065	23	72,721	1,065

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[a] In numbers of units, except that trails are measured in miles, campgrounds are measured in spaces for tents and trailers, group camp capacity is measured in number of persons accommodated, and picnic sites are measured in number of tables.

It is axiomatic that people cannot use an area unless it appears within their life space. In other words, people must be aware that an area exists before it will affect their behavior. Moreover, even if people are aware that an area exists they may not use it for a variety of reasons, such as sociocultural barriers to participation; concern about safety; lack of time, money or skill; or belief in any of a variety of misconceptions about the area or the services provided there.

Thus, the research we will undertake deals not with the total supply of recreational opportunities, but rather with the effective supply. Projects like this seem especially desirable because they permit us to educate the public about nearby recreation opportunities while we are gathering information.

II. Use of urban forest recreation areas

The tremendous growth in demand since World War II has shown beyond all doubt that forested recreation areas are highly attractive to the general public. We know, too, that separate demands exist for a wide range of activities like camping, hiking, hunting, fishing, etc.; and that each of these activities appeals to a different type of people. What we do not know is how people actually use an area. What do they do when they arrive at the site? Where do they go and why? What kinds of activities and behaviors do they engage in on the site? How long do they stay? When do they leave? If an area offers several activities, which one do most people select, and why? When an area offers several sites for the same activity, which sites do most people prefer, and why?

Knowledge of this type may prove valuable to managers. If we know more about how and why people actually use an area, it may be possible to adjust or modify its use to meet management objectives, by controlling the physical attributes of the landscape.

There is also, unfortunately, another category of use of urban recreation facilities that needs investigation: their illicit use. This is a large and growing problem in the parks of many major cities. By examining this problem in detail, we hope to provide some assistance to law enforcement officials. In addition, information on relationships between various kinds of crimes and physical attributes of parks may prove important to park planners and designers.

III. Meanings of urban forest recreation areas

The term meaning has a variety of uses, and often means different things to different people. Generally speaking, the meaning of an area or an activity to a particular user will depend on that person's structure of attitudes, values, beliefs, motives, and personality. For example, studies have shown personality differences between participants in different recreational activities (Moss, Shackelford, and Stokes 1969).

Particularly crucial to this concept is what the user expects to find at an area. Expectations, sometimes called aspirations in the recreational literature (e.g. Bultena and Klessig 1969), are beliefs about what will be present at an area. Understanding these expectations is a first step toward discovering what an area or activity means to people.

Research on the meanings of forest recreation activities and areas will be essentially basic research until more about the functions of such meanings can be discovered. A logical approach is to begin with informal, but in-depth, interviews with participants at recreation sites. From these interviews, more formal instruments may be developed. We expect that they will yield usable management information along the way, especially by finding out more about how users conceptualize forest recreation areas and activities,

IV. Benefits of urban forest recreation areas

The concept of benefits stemming from a particular area or experience is a complex one. To begin with, there are several different types of benefits. Some of the benefits of forested areas are physical: trees and forests in urban areas can modify microclimates (Federer 1971), reduce air pollution (Rich 1971), help in noise abatement (Leonard 1971), and play a role in neutralizing wastes (Sopper 1971).

A second class of benefits is primarily economic. A recreation area may benefit the local community by stimulating a demand for secondary goods and services, such as motels, gasoline stations, restaurants, etc. In some cases these benefits may be substantial, as they are in many of the communities around the national parks. In most instances, however, such benefits are small (Beardsley 1971).

Tombaugh (1971) has discussed two types of external economic benefits produced by natural environments: existence value and option value. Existence value is the pleasure people derive from knowing that an area exists, even if they don't plan to use it. Option value is people's willingness to preserve an area because they want to maintain their option to visit it. It may be that option values are especially important in the urban forest.

Another external effect, which may be unique to forests and parks in urban areas, is their influence on property values (Hammer, Coughlin, and Horn 1971; Kitchen and Hendon 1967). In general, these studies have found that parks increase property values, although results differ for properties bordering directly on the parks.

A third type of benefit produced by natural areas in and around cities is the effects they have on their visitors. Some of these effects are physical, such as improved muscle tone from vigorous exercise. Others might be social, such as increased family solidarity, decreased aggressiveness, or increased tolerance of different social groups. Other benefits are psychological, such as learning about the natural environment, the "re-creation" that restores one for work, need fulfillment, or wish gratification.

Research on all aspects of these recreational benefits is extremely important, especially for the urban forest, where suitable lands are rapidly being eroded by subdivisions and other land uses. Fortunately, a number of USDA Forest Service research units throughout the country are studying recreational benefits. We will attempt to coordinate work on the various types of benefits, and find ways to quantify them in standard units to make them comparable both with each other and with benefits of alternative land uses.

V. Choice of recreational activities in urban forest settings

This topic is basic to the other research topics discussed above. For example, it would be logical to assume that people choose the activity that promises the most benefits to them. These benefits depend on what they expect to find at an area, and upon what these expectations mean to them. However, the choice of activities or areas also depends upon their accessibility. This, in turn, depends on such variables as cost, distance, etc. As a topic for research, therefore, the problem of choice can serve an integrative function by indicating the nature of the relationships between some of these variables. In other words, work on this problem will help us evaluate the relative importance of such factors as accessibility, benefits, meanings, and so forth, in determining how people reach decisions about areas and activities.

Moreover, by understanding the bases of an individual's choice, we should also gain further understanding of the very foundations of recreational demand. This, in turn, could greatly augment our knowledge of the substitutability of different forms of recreation. Unfortunately, because of the integrative nature of this topic, work on it must be delayed until we have obtained positive results from research in the other areas.

CONCLUSIONS

I consider this analysis a starting point for our research efforts; it should not be considered the ultimate word on such ventures. In time as we amass more research results, some of these lines of investigation may prove unfruitful, while added experience will undoubtedly suggest new directions for research. Furthermore, these efforts in recreation research are only a part of the total thrust in the new areas of environmental and urban forestry. Constant coordination with work in other areas will be necessary if we are to attain our goal--building a substantial foundation of knowledge about people and forests that will facilitate the delivery of recreation to residents of the nation's large cities.

LITERATURE CITED

Beardsley, W. G. 1971. The economic impact of recreation developments: a synopsis. In Recreation symposium proceedings. p. 28-32. USDA For. Serv. Northeast. For. Exp. Stn., Upper Darby, Pa.

Bultena, G. L., and Klessig, L. L. 1969. Satisfaction in Camping: A conceptualization and guide to research. J. Leisure Res. 1(4):348-354.

Federer, C. A. 1971. Effects of trees in modifying urban microclimate. In Trees and forests in an urbanizing environment. Holdsworth Nat. Resour. Cent., Plann. Resour. Dev. Ser. 17:23-28. Univ. Mass., Amherst.

Gottman, J. 1961. Megalopolis. 810 p. Cambridge, Mass.: M.I.T. Press.

Hammer, T. R., Coughlin, R. E., and Horn, E. T. 1974. The effect of a large urban park on real estate value. J. Am. Inst. Plann. 40(July):274-277.

Kitchen, J., and Hendon, W. 1967. Land values adjacent to an urban neighborhood park. Land Econ. 43(3):357-360.

Leonard, R. E. 1971. Effects of trees and forests in noise abatement. In Trees and forests in an urbanizing environment. Holdsworth Nat. Resour. Cent., Plann. Resour. Dev. Ser. 17:35-38. Univ. Mass., Amherst.

Moss, W. T., Shackelford, L., and Stokes, G. L. 1969. Recreation and personality. J. For. 67(3):182-184.

National Recreation and Park Association. 1974. Open-space and recreation opportunity in America's cities. 155 p. U.S. Dep. Housing Urban Dev., Off. Community Plann. Dev., Eval. Div.

Rich, S. A. 1971. Effects of trees and forests in reducing air pollution. In Trees and forests in an urbanizing environment. Holdsworth Nat. Resour. Cent., Plann. Resour. Dev. Ser. 17:29-35. Univ. Mass., Amherst.

Shafer, E. L., Moeller, G. H., and Getty, R. E. 1974. Future leisure environments. USDA For. Serv. Res. Pap. NE-301,16 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Sopper, W. E. 1971. Effects of trees and forests in neutralizing waste. In Trees and forests in an urbanizing environment. Holdsworth Nat. Resour. Cent., Plann. Resour. Dev. Ser. 17:43-58. Univ. Mass., Amherst.

Tombaugh, L. 1971. External benefits of natural environments. In Recreation symposium proceedings, p. 73-77. USDA For. Serv., Northeast. For. Exp. Stn., Upper Darby, Pa.

U. S. Department of Agriculture. 1970. Land use and management. 264 p. N. Atl. Water Resour. Study.

U. S. Department of the Interior. 1974. The recreation imperative. 389 p. Washington, D.C.: Gov. Print. Off.

Wolfbein, S. L. 1954. The changing length of working life. In E. Larabee and R. Meyersohn (eds.) Mass leisure. p. 154-161. Glencoe, Ill.: The Free Press.

Zeisel, J. S. 1958. The workweek in American industry. 1850-1956. Mon. Labor Rev. 81(1):23-29.

A CRITIQUE OF THE PAPER ENTITLED "URBAN FOREST RECREATION: A STRATEGY FOR RESEARCH"

Philip L. Archibald[1]

Author Tom More's paper is well written and flows in a logical manner through the Abstract, Problem, Topics for Research (giving the proposed research project by the Northeastern Station) and terminating in the Conclusion.

The paper discusses the problems associated with providing increased amounts of recreation for urban dwellers--whose population is rapidly increasing. More pressures are being placed on providing recreation within the urban complexes. He points out that much of the past research and studies on recreation use and problems was focused on the rural areas.

His paper describes the research that will be conducted by the Forest Service's Northeastern Station within the Pinchot Institute for Environmental Forestry. This research work will study the problems and opportunities associated with outdoor recreation only in the Northeast, but assumes that the findings will be applicable to other areas of the country.

The immediate problem that the reader may encounter with More's paper is one of definitions, beginning with his definition of an urban forest. He writes that "This forest, interspersed with buildings, fields, houses, roads, fences, and private holdings, is the urban forest." He later hints that the urban forest is similar to the Interior Department's definition of an urban recreation complex which are areas within 120 miles of a city of 500,000 or more population.

The author defines the urban forest in his paper more in terms of geographic distances from the inner city and by population than in terms of plant cover or uses of the forested areas within urban complexes.

He states that "Access to the forest for recreational purposes will be limited." Yet, if we take his definition of the urban forest literally then those people living in the metropolitan areas are already in the urban forest.

Traditionally, we have thought of an urban forest as an entity within some geographic urban zone in the same category as an urban park, green strip, or developed recreation area--not in all encompassing nature, including homes, shopping centers, and industrialized areas. Perhaps the title of his paper should be "Urban Recreation Complex: A Strategy for Research," since forests are only a piece of the landscape that goes to make up the urban complex mix.

A clearer distinction is needed between parks (which may have trees) and urban or semi-urban forests. The two are mutually exclusive with different clientele, different ecosystems, different uses, and different problems.

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The reader may encounter more definition problems in the discussions of tables 1 and 2 dealing with recreation acreage, recreation land, and urban recreation. The author says that the Northeast contains 100 million acres of fields, marshlands, and woodlots, yet the recreation acreage per capita is only 0.2 acres. Then, "recreation land is even more scarce for residents of metropolitan areas: only 0.04 acres per capita." Evidently USDI, who gave these figures in "The Recreation Imperative," meant the acreage in developed sites within their "urban recreation complexes." Millions of acres of forested lands lie within the "complexes." These acres are available to the urban dweller for both developed and dispersed types of recreation. The reader may also have problems with the title of table 1 in "Public Ownership of Recreation."

On the first page in the Abstract and under The Problem it would be well for the author to state that the proposed research is to learn more about people and how they perceive and use urban forested recreation areas--and not so much about the forest itself.

While there will be more demand for recreation in the urban recreation complexes, his contention that recreation visits to the rural areas are presently declining is false. Recreation use to the National Parks and Forests is at an alltime high and increasing even in this period of rapid inflation and rising prices for gasoline. Perhaps people are taking that "last" major trip or vacation before the energy crunch descends upon them.

Society has certainly overlooked the need to research recreation use, problems, and opportunities in the urban areas especially as it relates to trees and forests. The Pinchot Institute is attempting to correct a small portion of this need. The author has listed many important key questions to which answers are lacking. Research into which recreational activities "buys" the most toward providing the effective supply of needs is important when we consider the billions of dollars worth of urban recreation needs which must be met in the future. The value of the forest, or tree associated, outdoor type recreation will compete for the more costly types of recreational activities--many of which often have high capital investments.

Research has been done on the use that is made of rural recreation areas. Studies at National Forest campgrounds have determined where people go, what they do, what activities they like best, how long they stay, and so on. The same information is urgently needed in the urban recreational complexes. Researchers should be reminded that attitude interviews are for that particular point in time and that these attitudes may change with economic conditions, health, age, and other factors.

While, as the author states, the proposed research project is not all encompassing, research needs which would be crucial to the urban recreation manager are: "How do we keep these urban forests healthy, vigorous, free from deleterious effects and then regenerate them whenever necessary--all in the urban setting?" Studies are needed to determine how much area is needed in urban forests, parks, and greenbelts per 100,000 population--classified by types such as high forest, urban park, mini park, or strips: How much is needed for recreation, amelioration of climate, noise reduction, and esthetics; do we design such areas, either starting from scratch or by redesign? These are among the questions which the hundreds of State and city urban and community foresters are attempting to answer as they work with urban planning and development associations and commissions in today's world.

TOPIC III

RESEARCH APPLIED TO MANAGEMENT PROBLEMS

ABSTRACTS

ELSNER AND TRAVIS

The Role of Landscape Analytics in Landscape Planning.--This paper defines the emerging field of landscape analytics and discusses some of the more practical aspects of computerized landscape analytics, and relates it to the larger fields of landscape planning and land-use planning. The paper also summarizes some of the more important theoretical systems for dealing with landscape dimensions and measurements, outlines our own work with the VIEWIT system, and makes suggestions for future work in this field.

WAGAR

Achieving Effectiveness in Environmental Interpretation.--To contribute fully to sustained resource benefits, interpretation needs support for recruiting and retaining top-flight interpreters and for research in interpretation. Summaries of existing knowledge and new studies show that interpreters' effectiveness can be improved by (1) defining clear objectives, (2) using attention-holding techniques, and (3) evaluating the extent to which objectives are achieved.

CONVERY

Economics Applied to Outdoor Recreation: An Evaluation.--The uses and limitations of economics for outdoor recreation planners and managers are discussed. Special attention is devoted to the estimation of costs and benefits of providing outdoor recreation, and the extent to which such estimating procedures can be used by field personnel.

LIME

Principles of Recreational Carrying Capacity.--Recreational carrying capacity is a complex and troublesome concept that incorporates principles of the social as well as the physical and biological sciences. There is no magic number that is the capacity for a given recreation site. Deciding how much and what kind of use is acceptable for an area must be based on managerial judgment and experience. The uncertainty of such decisions can be substantially reduced by a consideration of the interrelationships of (1) management objectives, (2) recreation user attitudes, and (3) impacts of recreation use on natural resources. Some basic principles, based on a review of the current state-of-the-knowledge, that relate to carrying capacity and that seem relevant to outdoor recreation management are discussed.

HENDEE AND POTTER

Hunters and Hunting: Management Implications of Research.--Data are summarized from 33 studies pertaining to hunting participation--hunter characteristics including age, education, occupation, income, residence; hunter motives; membership in sportsmen organizations and reading of sporting magazines; antihunting sentiment; and nonconsumptive wildlife use. These data are interpreted for implication about the future importance and nature of hunting and wildlife management. The authors see the continued importance of hunting but perhaps at reduced levels. The provision for the integration of opportunities for both hunting and wildlife appreciation are an important resource management challenge.

THE ROLE OF LANDSCAPE ANALYTICS IN LANDSCAPE PLANNING

Gary H. Elsner and Michael R. Travis[1]

Abstract.--This paper defines the emerging field of landscape analytics and discusses some of the more practical aspects of computerized landscape analytics, and relates it to the larger fields of landscape planning and land-use planning. The paper also summarizes some of the more important theoretical systems for dealing with landscape dimensions and measurements, outlines our own work with the VIEWIT system, and makes suggestions for future work in this field.

Additional keywords: Landscape analytics, landscape planning, land-use planning, computer models, analysis methods, landscape research.

INTRODUCTION

This paper introduces and discusses several of the components of the emerging field of landscape analytics. Landscape analytics is concerned with the development of quantitative information about the landscape as contrasted with quantitative information about people's perception or satisfaction relative to the landscape. But before discussing how landscape analytics are related to landscape and land-use planning, we need to touch on the role of landscape analytics in landscape research; the distinction between landscape analysis that is done with respect to an observer and analysis that is done without respect to an observer; and the differences between computerized and manual analysis.

LANDSCAPE MANAGEMENT RESEARCH

Framework

To facilitate more precise communication concerning Forest Service landscape research programming, a team[2] of Forest Service researchers met in San Antonio, July 7-11, 1975, to develop a conceptual framework for Landscape Management Research (fig. 1). This framework delineates distinct landscape research areas, and clarifies their relationships to land-use planning.

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[2] Team members were: R. O. Brush, B. L. Driver, H. E. Echelberger, G. H. Elsner, R. G. Lee, R. B. Litton, A. W. Magill, and E. L. Shafer.

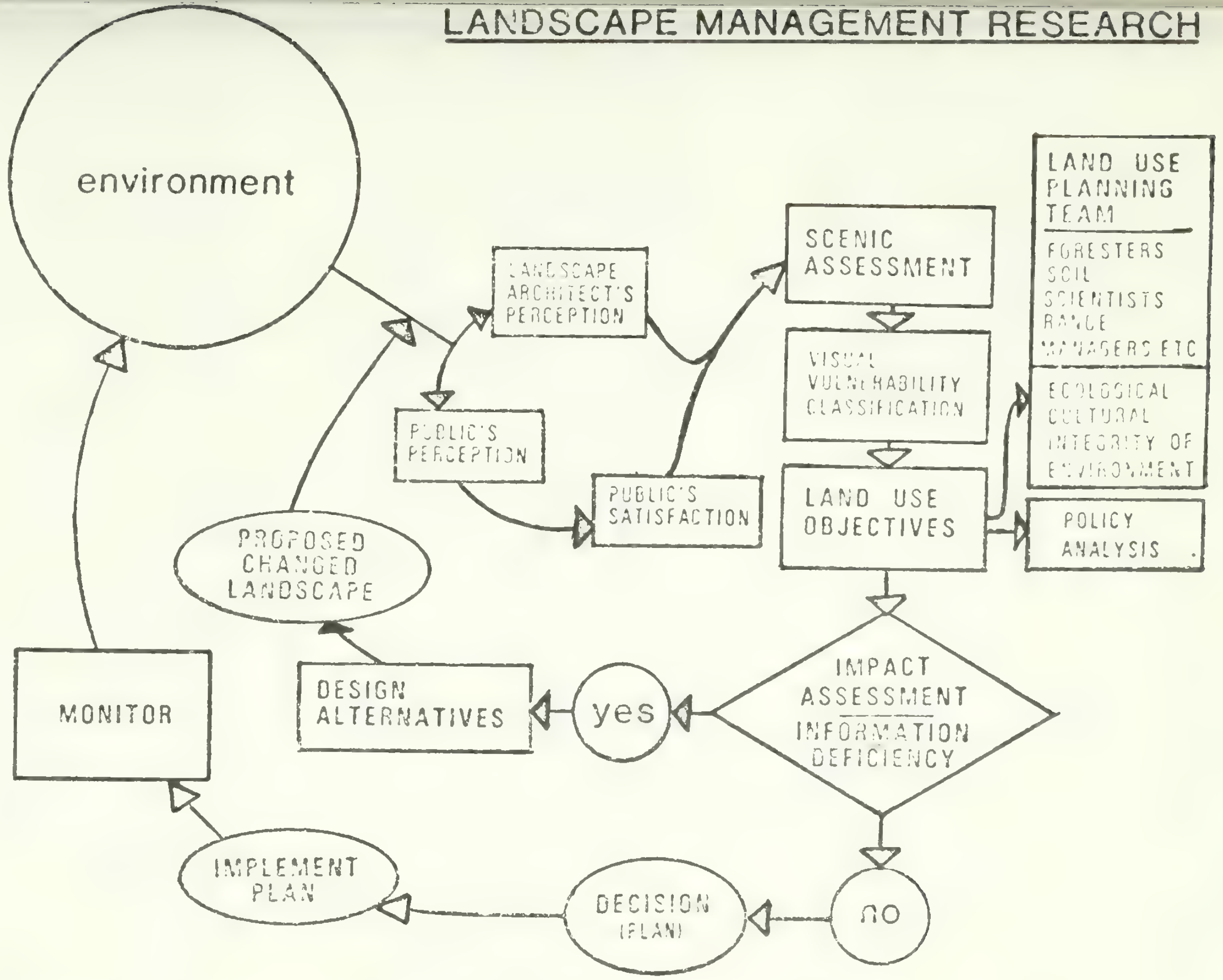

Figure 1.--A conceptional framework for landscape management research by the U. S. Forest Service.

The broad areas for landscape research are described by these titles:

Public perception

Public satisfaction

Landscape architect's perception

Scenic assessment

Visual vulnerability classification, which is sometimes termed visual absorption capability (Litton 1974)

Land-use objectives

Design alternatives

Plan implementation

Monitoring activities (Litton 1973)

The land-use planning activity shown in the framework provides both an emphasis to the importance of landscape analysis and a means of attaining and monitoring esthetic values. This landscape research framework was designed to conform to generalized land-use planning procedures, which include all those elements from the statement of land-use objectives and goals, through definition of alternatives, to impact assessment, plan implementation, and monitoring. Therefore, the correspondence between elements in the landscape research framework and similar elements in the planning process can be used to judge the effectiveness of new information or new technology developed by landscape researchers. By helping to define and quantify the basic dimensions of the landscape, the field of landscape analytics contributes to improved communication and understanding in each of these areas.

Alternative Categorizations

This framework is not intended to be the final answer to categorizing landscape research. In fact, several alternative categorizations have already been proposed. For example, Wagar (1974) has defined three categories for studies of landscape quality: (1) physical descriptions, (2) judgments of quality, and (3) analyses of psychological dimensions involved in landscape preferences. And the Environmental Protection Agency (EPA) commissioned an important review of esthetics in environmental planning (Washington Environmental Research Center 1973).[3] This review defined and utilized the following categories for visual and user analysis methods:

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[3] The report for the EPA reviews a number of selected methods and includes a fairly comprehensive reading list.

Visual Analysis Methods

1. Numerical systems for visual analysis--comprehensive environmental analysis

2. Numerical systems for visual analysis--independent esthetic assessment methods

3. Non-numerical visual analysis methods

User Analysis Methods

Methods of visual analysis are those tools used to identify esthetic attributes, to forecast changes in the attributes, and to describe the implications of changes for the environment. Methods of user analysis are used to evaluate individual preferences for esthetic stimuli. The three methods of visual analysis defined for the EPA depend upon whether esthetic characteristics are assigned numerical values or are only ranked. If a method attempts to relate esthetic considerations to other environmental considerations, it is termed a "comprehensive environmental analysis method." If the method is designed to assess esthetic impact as an independent environmental consideration, it is termed an "independent esthetic assessment method" (Washington Environmental Research Center 1973, p. 41).

While these categorizations are helpful in understanding landscape research, they do not clarify its relationship to land-use planning nor depict the difference between those methods which may be designed and used by the planner or landscape architect and those which may be used by the general public.

The rest of this paper is concerned chiefly with computerized landscape analytics or those methods and measures which would be termed "Visual Analysis Methods: numerical systems for Visual Analysis--independent esthetic assessment methods."

Analyses of Visual Quality Characteristics

Most applied approaches to landscape analysis seem to place some importance upon first determining which areas of the landscape comprise specific landscape scenes or visible areas (Lovejoy 1973). And the scene delineation is often treated in a multiple form; that is, not from a single observer point, but from many points defining a highway route or from many frequently visited points in the landscape.

An elaboration of this concept is employed in the Forest Service's Visual Management System (VMS) for setting visual quality objectives (USDA Forest Service 1974). This approach of first determining seen areas or landscape scenes and then determining and mapping characteristics of those seen areas is clearly depicted by Zube and others in their Connecticut River Valley Study (Zube and others 1974). This approach is particularly appropriate for analyzing visual impact from specific land-use proposals as they occur; that is, for dealing with unpredictable demands upon the landscape. But in many long-range planning processes, such as VMS, it is also necessary to identify and map visual quality characteristics independent of whether the area comprises a specific landscape scene or not. It is reasonable to expect therefore, that those computerized landscape analysis systems that provide both kinds of capabilities would receive the widest usage.

MANUAL LANDSCAPE ANALYTICS

Manual approaches to landscape analysis are well established and have been in practice for many years (Litton 1968). Additionally, some of the same techniques of manual view delineation have an even longer history in the planning of forest fire lookout systems. Procedures for producing visibility maps by field sketching have been well documented since at least 1931 (Shank 1931). Manual profile, photographic and relief-model methods for producing visibility maps for planning forest fire lookout systems were published in 1937 (Show, Kotok, and others 1937).

Although computerized methods for view delineation have been available for some time (Amidon and Elsner 1968), more advanced computerized approaches to these and other problems have only recently received widespread usage. The CLA system developed by the Forest Service is the VIEWIT system (Amidon and Elsner 1968), (Elsner 1975), (Travis, Elsner, Iverson, and Johnson 1975). This large-capacity, visual-analysis system was designed to complement several other Forest Service systems, including TOPAS (Topographic Analysis System). The VIEWIT system was reviewed in the EPA report (Washington Environmental Research Center 1973) and compared with the manual methods developed by Leopold (1969)[4] and by Burke and others (1968) using five different criteria. The summary table (fig. 2) from the EPA report is informative and useful but somewhat arbitrary--it could be expanded both in its list of relevant criteria and in the systems to be compared. Moreover, the VIEWIT system can now handle larger planning areas and has many more options than in 1973.

COMPUTERIZED LANDSCAPE ANALYTICS

The previous discussion has given an idea of what computerized landscape analytics is and how it differs from other parts of the landscape planning and management job and in general how it relates to the job of land-use planning. This section will discuss in some detail the situations in which CLA is appropriate, CLA audiences or user populations, the types of landscape dimensions which can be incorporated into CLA, and a sample of the specific computational capabilities of the VIEWIT CLA system.

Application Criteria

Any manual landscape analysis involves considerable time, often solely by landscape architects. And any CLA application involves a commitment of experts in data handling and landscape architecture, as well as computer processing costs. It seems relevant, therefore, to consider carefully some of the advantages and disadvantages of the proposed computer application. These eight broad considerations supplement the five criteria illustrated in figure 2:

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[4] A more detailed discussion of Leopold's method has been published recently in the Journal of Leisure Research (Hamill 1975).

1. Are visual resources of great importance in the proposed project or land-use planning activity? Will they have major or significant effects on decisions?

2. Can the visual analysis be handled through other means with less investment?

3. Does the user have access to a high-speed printer terminal or small demand terminal? If not, can the user work with the turn-around time involved in mailing input and output data from other offices? Or can work be handled by short details of individuals to such offices?

4. Do several alternative land-use plans need to be evaluated?

5. Is there high potential for future use of the input data after its initial usage? For instance, would there be possibilities of power transmission, road, timber sale, electronic relay site, etc., proposals within this land unit?

6. Will computer-generated output be accepted or required by management and the public as valued information for decisionmaking. Will quantitative estimates of visual impacts of alternative land uses be useful in developing land use or project plans?

7. Is there a need for consistent and repeatable analyses? Is the required level of detail or the land area so extensive or the number of observer points so large that manual analyses would consume an inordinate amount of time?

8. Is the topography of the area complex, i.e., does it contain hilly or mountainous zones which would make manual landscape analysis very time consuming?

User Groups

Essentially any organization that is responsible for managing large areas of land with significant visual resource values may want to consider using CLA. If the land is also subject to frequent development pressures or use demands or both, then a computerized analysis system may help save time and money. The groups which we have worked with on the VIEWIT system include associations of metropolitan governments, universities, and Federal land management agencies such as the Forest Service, National Park Service, Bureau of Land Management, and the Army Corps of Engineers (Travis and others 1975).

Criteria	Leopold's uniqueness study (numerical scale)	Burke (photographs)	VIEWIT (computerized)
(1) Generated from public experience not developers biases	(-) Subjective selection of preferred characteristics	(-) Developers biases define beauty and interest	(+) Totally objective, only areas physically visible are computed
(2) Full range of aesthetic attributes	(+) Aesthetic factors considered in detail, good range	(+) Full range indicated	n.a. Objects not described
(3) Variables appropriate to scale and purpose of system	(+) Site related	(+) Views by zone--corridor related	(+) Site related
(4) Primary aesthetic and secondary aesthetic impacts considered	(-) Primary only	(-) Sensitive areas not adequately described	n.a.
(5) Measured against established reference point	(-) Ranked independently	(-) Characteristic landscape not described well	(+) Is it visible or not
(6) Straightforward and easily reproduced	(+) Data appropriate and adequately described	(+) Photos primarily	(+) Topo map reading and computer data
(7) Output easily communicated	(-) Ranking criteria not explained well	(-) Subjective values predominate	(+) Informative but limited in usefulness

Source: Washington Environmental Research Center (1973)

Figure 2.--A numerical system for visual analysis (independent esthetic assessment) compares an early version of the VIEWIT computerized technique with manual methods developed by Leopold (1969) and Burke (1968). (-) indicates that the system does not satisfy corresponding criteria. (+) indicates that the system satisfies criteria adequately.

Quantitative Landscape Dimensions

The basic and most useful reference in identifying landscape dimensions is Litton's (1968) report, even though it is not oriented towards computerization. In a more quantitative approach to the problem, Zube and others (1974, p. 37-45) have reviewed the literature and identified six major categories of landscape dimensions: landform, land-use area, land-use edge, land-use contrast, water, and views. And for each category, they have suggested alternative measurements, which are calculated manually (p. 163-180). The landscape dimensions and alternative measures are:

1. Land form

    Relative Relief Ratio
    Absolute Relief Ratio
    Mean Slope Distribution
    Topographic Texture
    Ruggedness Number
    Spatial Definition Index
    Mean Elevation

2. Land-Use Area

    Land-Use Diversity
    Naturalism Index
    Percentage Tree Cover

3. Land-Use Edge

    Land-Use Edge Density
    Land-Use Edge Variety
    Land-Use Compatability

4. Land-Use Contrast

    Height Contrast
    Grain Contrast
    Spacing Contrast
    Evenness Contrast
    Naturalism Contrast

5. Water

    Water Edge Density
    Percentage Water Area

6. View

    Area of View
    Length of View
    Viewer Position

VIEWIT Calculation of Landscape Dimensions

This section summarizes the VIEWIT system's capability of computerizing several measurements of land form and view as well as combine the analyses with independent calculations of the remaining landscape dimensions or with other resource characteristics. The relationship of some of these basic calculations to the job of assessing landscape resources has been detailed by Iverson (1974).

Two types of landscape dimension calculations are currently used: in one, a single number is calculated for a viewed area; in the other, a number is calculated for each cell of the landscape to produce a map of results. Generally, Zube's method follows the first approach, while VIEWIT provides both capabilities. VIEWIT provides a map overlay, summary tables, and statistics for each measurement, and has an option for outputting these results for combining with other data.

View Calculations

Area of View

The VIEWIT system calculates the area of view from one or more points. The results may be displayed on tables in terrain cells, square miles, acres, or hectares or on overlay maps in numeric or gray shade form.

Aerial View Analysis

The seen-area analysis can be computed from a point either above or below the actual land surface. Thus, it can simulate the view from or of a proposed elevated structure, or a proposed surface mining area or, with a number of observation points, the view from a helicopter or airplane in flight.

Times Seen Analysis

The area of view may be determined from a single observation point or from several observation points. In this latter case, the number of times cells can be seen is recorded. These results can be displayed as a number or as a percentage of the total number of observation points.

Length of View

The maximum length of view can be determined quickly by examining the overlay map of the view area.

Viewer Position

Observer or viewer position is a term defined by Litton (1968, p. 5-10) to describe the location of the observer as to the viewed landscape. If the observer is below the surrounding landscape, the position is "inferior"; if the observer's level line of sight generally coincides with the dominating elements of the landscape, then the position is "normal"; and if the observer is located above the bulk of the viewed landscape, the position is "superior."

With the VIEWIT program the user may specify that seen-area analysis be performed with respect to any one of these three observer positions.

That proportion of the visible landscape which is situated above the observer's level line of sight (i.e., observer inferior position) can be calculated by setting two vertical angle controls. For example, when the level line of sight is treated as 0°, these controls would be placed at 90° and 0° for the observer's inferior position. Similarly, the visible landscape below the level line of sight (i.e., observer superior position) can be calculated by setting these control angles at 0° and -90°. And a range around the level line of sight (for the observer normal position) can be calculated by setting the angles at 15° and -15°.

View Area--Weighted by Distance

Another option allows the visibility of a cell to be weighted by its distance from the observer. To do this the user specifies the distance weighting function most appropriate for the current analysis. Rather than have a limited set of distance functions available to the user, the system allows the user to define any function. This combination of seen area weighted by distance (Yajima 1968) may, of course, be determined from many observation points with the same distance weighting function. Or the weighting function may be changed for different viewing points.

Relative Aspect Analysis

Relative aspect is a measure of the orientation of a visible cell with respect to the observer. Each cell is assigned a maximum of 10 points, and is scaled according to the magnitude of the relative aspect. For example, a cell seen head-on will receive a weight of 10. But if a cell is turned partially away from the observer so that its apparent area is only one-half of its actual area, it will receive a weight of five points. This analysis can be carried out for multiple observer points. Either the average or the maximum of the relative aspect weights combined with the times seen calculations can be computed.

View Area--Weighted by Relative Aspect and Distance

Either relative aspect or distance weighting or both can be used for any observer point or points in a series of visibility analyses.

and Form Calculations

Absolute and relative relief measurements are computed directly from the levation data. The elevation data can be portrayed by the VIEWIT system ither as a coded overlay map that shows the elevation for every cell or as a ray-shaded map with higher elevation shaded in darkest tones.

Absolute Relative Relief

The absolute relative relief measurement is the standard deviation of the visible elevation data.

Relative Relief Ratio

The relative relief ratio is calculated by dividing the absolute relative relief by the area of view.

Mean Slope Distribution

Slope information can be calculated and produced either as overlay maps or as table information. The slope classes may be defined either by standard 10 percent classes or by any set of classes the user specifies. The mean slope distribution is then simply the average of the number of acres or hectares of land in each slope class.

Absolute Average Elevation Change

With this measurement the average elevation of the eight cells around each cell is computed. And the ratio by which the elevation of the cell differs from this average is recorded.

Aspect

Aspect is the primary direction in which the land form slopes. Aspect is calculated by the computer by first finding the best fit plane to approximate the slope of the terrain and then determining its principal compass direction. Aspect may be calculated and displayed in a variety of ways including 10° or 45° segments ordered clockwise or both clockwise and counter-clockwise from a specified direction. Since the user may specify any aspect, the option may be used to produce gray-shade maps, with darkest shades showing those areas which have an aspect nearest to the specification. For example, northeast maps may be produced to identify snow retention for ski runs or water retention for revegetation, or southeast aspect maps for the morning sun preferred for campgrounds. Several aspect maps from different directions give additional insight into the shape and orientation of the land form.

Summary Statistical Measurements

Several standard statistical measurements can be computed from either the basic elevation data or the results of slope, aspect, and other options. These measurements include the mean, minimum, maximum, variance, standard deviation, skewness, and kurtosis. Standard deviation is a measure of absolute dispersion or spread of the data. Skewness and kurtosis are measures of relative dispersion. Specifically, skewness is a measure of the degree of asymmetry. And kurtosis is a measure of the degree to which the distribution of the data is peaked.

The Future for Landscape Analytics

Clearly, current research and development emphasis in landscape analytics is largely on identifying and defining landscape dimensions which can be calculated either manually or by computer and in evaluating and comparing alternative measurements for each dimension. We expect that this type of exploratory and evaluation work will need to continue for some time.

Research and development efforts beyond this will probably focus upon evaluating the practicality of estimating and utilizing indexes of landscape quality and user preference and preference functions for landscape esthetics. These efforts would be similar but more detailed than those described in a recent paper on illustrative preference functions for water esthetics (Gum and others 1974, p. 42-50). The next steps will probably be related to developing and evaluating the usefulness of production functions for landscape esthetics, which may or may not be stated as joint production functions with other forest outputs.

As worthwhile landscape analytic techniques are developed, researchers and managers will continue to work together to incorporate these ideas into planning processes.

SUMMARY

Because of the many talented and original minds now at work on landscape analytics, significant developments continue to be published at a steady rate--both in the United States and throughout the world. It is likely to be some time, therefore, before anything like a comprehensive treatment of this dynamic and important field becomes possible. This discussion of some of the more practical aspects of computerized landscape analytics has defined the subject, related it to the larger fields of landscape planning and land-use planning, summarized some of the more important theoretical systems for dealing with landscape dimensions and measurements, outlined our own work with the VIEWIT system, and made some suggestions for future work in this field.

LITERATURE CITED

Amidon, Elliot L., and Gary H. Elsner. 1968. Delineating landscape view areas...a computer approach. USDA Forest Serv. Res. Note PSW-180, 5 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

Burke, Herbert D. et al. 1968. A method for classifying scenery from a roadway. Park Practice Guideline, Development Section, Item No. 22, p. 1-17. Published by Natl. Conf. on State Parks, Am. Inst. of Park Ex., and Natl. Park Serv., U. S. Dep. of Inter., Washington, D. C.

Elsner, Gary H. 1975. Computer management of recreation data: terrain and usage studies for land-use planning. Proc. Soc. Am. For. Systems Analysis Workshop, Athens, Ga., Aug. 11-13, 1975. (In press)

Gum, Russell, Robert Judge, Dan Kimball, and Weston Wilson. 1974. Quantifying aesthetic opportunity. A report submitted to U. S. Army Eng. Inst. for Water Resourc., Fort Belvoir, Va., by Utah State Univ., Logan, Utah.

Hammill, Louis. 1975. Analysis of Leopold's quantitative comparisons of landscape esthetics. J. Leisure Res. 7(1):16-28.

Iverson, Wayne D. 1974. Assessing landscape resources--a proposed model. In Landscape Assessment: Values, Perceptions and Resources. E. Zube, J. Fabos, R. Brush, ed. Dowden, Hutchinson and Ross, Inc. Proc. Conf. on Landscape Assessment, Univ. Mass., Nov. 15-16, 1973.

Leopold, Luna B. 1969. Quantitative comparison of some aesthetic factors among rivers. U. S. Geol. Survey, Cir. Bu. 620, 16 p. Washington, D. C.

Litton, Jr., R. Burton. 1968. Forest landscape description and inventories--a basis for land planning and design. USDA Forest Serv. Res. Pap. PSW-49, 64 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

______________ 1973. Landscape control points: a procedure for predicting and monitoring visual impacts. USDA Forest Serv. Res. Pap. PSW-91, 22 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

______________ 1974. Visual vulnerability of forest landscapes. J. For. 72(7):392-397.

Lovejoy, Derek, ed. 1973. Land use and landscape planning. 308 p. Leonard Hill Books, Aylesbury, Bucks HP20 ITL, Great Britain.

Shank, H. M. 1931. Visibility maps by field sketching. J. For. 29(4):526-532.

Show, S. B., E. I. Kotok, George M. Gowen, J. R. Currey, and A. A. Brown. 1937 Planning, constructing and operating forest-fire lookout systems in Californi USDA Cir. 449, 56 p.

Travis, Michael R., Gary H. Elsner, Wayne D. Iverson, and Christine G. Johnson. 1975. VIEWIT: computation of seen areas, slope and aspect for land-use planning. USDA Forest Serv. Gen. Tech. Rep. PSW-11, 70 p. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

USDA Forest Service. 1974. National forest landscape management, volume 2. Chapter 1, the visual management system. USDA Agric. Handbk. 462, 47 p. U. S. Gov. Print. Off., Washington, D. C.

Wagar, J. Alan. 1974. Recreational and esthetic considerations. In Environmental effects of forest residues management in the Pacific Northwest: a state-of-knowledge compendium, Owen P. Cramer, ed. USDA Forest Serv. Gen. Tech. Rep. PNW-24, 15 p. Pacific Northwest Forest and Range Exp. Stn., Portland, Oreg.

ashington Environmental Research Center. 1973. Aesthetics in environmental planning. Socioecon. Environ. Stud. Series, 188 p. Off. Res. Dev., U. S. Environ. Prot. Agency, Washington, D. C.

ajima, Ginosuke. 1968. Examination of sightseeing development planning of the Hakone, Yugawara area. 143 p., illus. Transport. Plann. Div., Tokyo Univ. (In Japanese.)

ube, Ervin H., David G. Pitt, and Thomas W. Anderson. 1974. Perception and measurement of scenic resources in the southern Connecticut River Valley. Inst. for Man and His Environ. Pub. R-74-1, 191 p. Univ. Mass., Amherst, Mass.

A CRITIQUE OF THE PAPER ENTITLED "THE ROLE OF LANDSCAPE ANALYTICS IN LANDSCAPE PLANNING"

Robert H. Stignani[1]

This paper essentially presents an up-date or state-of-the-art discussion which is most informative to those having a continuing interest or familiarity with the subject. Several aspects of this paper surface as outstanding strengths in an area long in need of clarification. The presentation of this subject in a manner that is readily understood by non-research oriented managers is in itself a strong point.

A basic problem related to research has been that of tracking the thread of continuity through to management application. The graphic portrayal of a conceptual framework for identifying landscape research areas is a significant effort to clarify this frequently obscure connection. Perhaps it might have been of value to expand upon this aspect of the paper, identifying specific examples of the research area correlation. "Visual vulnerability" might have been broken down further, for purposes of illustration, to measurements of slope, site regeneration capability, vegetative screening, etc. This point is, however, secondary to the primary topic.

Although the authors indicate that a totally comprehensive treatment of the subject is not possible due to the rapid advances being made by many researchers, the discussion under "Alternative Categorizations" was of help in comparing various research approaches.

A main thrust of the paper deals with computerized landscape analysis and builds a fairly strong case for use of the VIEWIT method. The concise and straightforward manner of presentation should cause the land manager little difficulty in determining whether or not to utilize a computerized analysis approach, and what quantitative landscape dimensions can be treated or interrelated.

This critique was based primarily on an earlier draft of the paper. It included references to program "user commands," undefined statistical terminology (e.g., standard deviation), and failed to cite examples of practical application for calculated landscape dimensions. The earlier draft also did not adequately define the term "landscape analytics" and establish the need for its use in lieu of the more familiar "landscape analysis." The subsequent revision recognized these shortcomings, and the several changes contribute to the improved communication which characterizes this paper.

There were a few areas that might have been expanded. Little if any reference is made to data input needs or alternative methods to secure input for the VIEWIT system. In a discussion of this nature, it might have been of value to include a flow diagram or sequence of steps leading to a management decision-related output as a summary or overview of the VIEWIT method.

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Most managers with varying backgrounds and knowledge of VIEWIT or similar topographically based computerized analysis programs might benefit from further mention of the constraints which either are inherent or have yet to be resolved. Such factors as vegetative cover, particularly where heights of timber vary considerably, minimum application considerations, both in terms of elevation differences and project scope, and accuracy constraints established by input data should be important in this type of discussion.

Although the authors make no claim in this regard, it perhaps should be pointed out that computer systems provide no decisions or subjective judgments. The process or "tool" is only an aid in decision-making, by providing the manager a more factual basis for which to make his subjective value judgment.

In their look ahead, Elsner and Travis conclude that it will be necessary to continue, for some time, to identify or define new calculable landscape dimensions and explore and evaluate their alternative measurements. This reviewer is optimistic that researchers will not become overly engrossed with this phase of this rapidly emerging field before charging ahead with other investigations along a broader front. The mere reference to "indexes of landscape quality and user preference" and "joint production functions (for landscape aesthetics) with other forest outputs" whets the appetite of land planners and managers.

ACHIEVING EFFECTIVENESS IN ENVIRONMENTAL INTERPRETATION

J. Alan Wagar[1]

Abstract.--To contribute fully to sustained resource benefits, interpretation needs support for recruiting and retaining top-flight interpreters and for research in interpretation. Summaries of existing knowledge and new studies show that interpreters' effectiveness can be improved by (1) defining clear objectives, (2) using attention-holding techniques, and (3) evaluating the extent to which objectives are achieved.

Additional keywords: Resource management, recreation, environmental education, conservation, evaluation.

THE SITUATION

Environmental interpretation--such as that found in visitor centers, interpretive trails, and talks by naturalists--has grown increasingly important in recent years. One reason is the great opportunity interpretation offers for increasing human enjoyment without increasing human impacts on resources. Many recreationists are delighted by interpretation that helps them understand the places they visit--for example, how people really lived in some other era (as at Colonial Williamsburg), how cave salamanders harness solar energy (as at Blanchard Springs Caverns), or how a geyser works (as at Yellowstone).

Growing public concern with environmental problems has also contributed enormously to the importance of interpretation. Not only do people recognize increasingly that sound resource management is essential for their future well-being, they also insist increasingly on participating in decisions about environment. Environmental interpretation can improve the quality of these decisions by helping people understand the dynamics of the ecosystem on which we all depend. As the complexity of environmental management increases, such understanding is increasingly essential for responsible citizenship.

The fundamental challenge to environmental interpretation, like the fundamental challenge to all other resource management, is to increase the sustained flow of benefits our resources provide for people. The problems that need to be addressed by research in interpretation are those things that prevent interpretation from contributing fully to this sustained flow of benefits.

Two kinds of problems limit the effectiveness of interpretation: policy problems and technical problems. Although researchers do not set policy, they can often help identify policy bottlenecks and make the policy-maker's task easier. Technical problems avoid most of the value judgments inherent in policy matters and are therefore much tidier and more "scientific".

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[1] Leader of Recreation Research Project maintained by Northeastern Forest Experiment Station, USDA Forest Service, in cooperation with State University of New York College of Environmental Science and Forestry, Syracuse.

However, we can't expect technical solutions to problems that are rooted in policy.

The major problem facing interpretation is the lack of support it receives within the agencies that administer a lot of the resources that lend themselves to exciting interpretation (Oltremari 1974). Several factors contribute to this. Perhaps the most important is that the training, job assignments, and incentives of most resource managers make them perceive themselves as specialists dealing primarily with physical resources rather than with human well-being. Public contact and the direct production of public enjoyment therefore tend to be considered incidental or as by-products permissible only to the extent that they don't interfere with "normal" resource management.

These attitudes are inestricably tangled with other factors. From our Puritan heritage there lurks a lingering distrust of anything so frivolous as the direct pursuit of pleasure. As a result, the enjoyment provided by interpretation usually goes under such serious sounding labels as "enrichment" or "enhancement" of visitor experiences. Often enjoyment is overlooked altogether, and interpretation is portrayed instead as a means to some other end, such as convincing people to use resources more wisely or convincing them that controversial management procedures are"correct".

Limited appropriations are often cited as the reason some things don't happen. These are a factor, especially lately. But, because of long standing value orientations, agencies that give high priority to their traditional work tend to give rather low priority to interpretation.

Perhaps another factor is simply that our philosophy of land use is still highly fragmented. Specialists often see their objectives as producing specific classes of products. If we ever get our land use philosophy all together, we'll discover that these products are means to sustained human benefits, not ends in themselves. On that glorious day, managers of public resources may be found derelict in their duty if they default in making resources yield the full measure of benefits for which they are suited, including benefits available through interpretation.

WHAT WE HAVE LEARNED

Research in interpretation has concentrated on four matters: recruitment and career ladders for interpreters, the role of objectives, gaining and holding attention, and evaluation of effectiveness.

Recruitment and Career Ladders

As one step in addressing the policy problems faced by interpretation, a study was launched to examine the ways interpreters are recruited, trained, and utilized in the Forest Service and National Park Service (Oltremari 1974). This was prompted, in part, by a suspicion that, during a buyer's market for talent, agencies were not recruiting and utilizing the best available people for interpretation.[2]

Some important patterns emerged. The interpreters sampled had most of their training in what to interpret and practically none of it in how to interpret. The preponderance of respondents in both agencies had concentrated their college coursework in such life and earth sciences as biology, botany, zoology, and geology. The next most common area was social science, followed by resource or land management. Although most respondents had taken at least one course in speech, few had taken such communications courses as journalism, radio and television, or dramatics. Yet they rated such courses as highly desirable preparation for their work.

Recruitment patterns suggested a rather casual approach to selecting public-contact personnel. More than half of the interpreters had been hired by noninterpreters, often with no interview.

Perhaps the most discouraging finding of the study was the lack of suitable career ladders for interpreters in either agency. Less than a quarter of the respondents were sure they would remain in interpretation, citing as reasons both limited agency support for interpretation and better opportunities in other fields. Over half of the respondents said they would have to leave interpretation to get promoted.

As mentioned, research can help identify such bottlenecks to performance as hit-or-miss recruitment and limited career ladders. However, solutions to these problems require policy changes rather than more study. In contrast with these policy problems, which involve what we choose to do and some of the constraints on our choices, technical problems concern how effectively we are accomplishing what we have chosen to do.

In the few studies addressed specifically to interpretation--and in the great amount of related research in education, communications, and psychology--three major points stand out: 1. We need clear objectives that define what we are trying to accomplish. 2. Messages must attract and hold the attention of the audience for whom they are intended. 3. Evaluation is needed to show how well objectives are being achieved.

OBJECTIVES

To be effective means to achieve your objectives. But many interpreters do not state clear objectives that specify exactly what they are trying to accomplish. Or, they often state objectives in such general terms as "interpret the natural and scenic attractions of Horsethief Valley". Although this is a fine statement of intentions, it provides no basis for knowing when the attractions of Horsethief Valley are being effectively interpreted.

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[2] Questionnaires were mailed to the 383 Forest Service people (nationwide) identified as being permanent or seasonal interpretive personnel and the 178 National Park Service people (Pacific Northwest Region only) identified in similar positions. Response rates were 85.6 percent for the Forest Service and 73.7 percent for the National Park Service.

To facilitate evaluation, we can borrow the idea of behavioral objectives from the educators (Mager 1962). Behavioral objectives specify what a student--or visitor--should be able to do as a result of a presentation. An example would be: "After hearing the naturalist talk at Horsethief Valley, the visitor should be able to name and describe the three major forces that shaped the valley". Accomplishment of this objective can be tested by conversation with the visitors or by occasional questioning.

Because behavioral objectives tend to focus on such fine points that broader goals could be overlooked, we can develop a pyramid or hierarchy of objectives (Putney and Wagar 1973). In this, each broad goal is supported by several specific objectives which, if achieved, contribute toward accomplishment of that broad goal. Each of these specific objectives may in turn be supported by several even more specific objectives to provide a pyramid with three or possibly even more layers. When objectives are stacked in such a hierarchy, demonstrated achievement at the most specific level permits us to infer similar achievement of broader goals, even if such goals are not suited to direct evaluation.

In developing objectives, we must not overlook what motivates our audiences. Instead of seeking information, many visitors to interpretive programs are simply engaged in an open-minded search for new and enjoyable experiences. In our closeness to the objectives of the organizations we serve, we must not concentrate on what we want people to know without considering why in the world they would enjoy knowing it.

AUDIENCE ATTENTION

Once we know in some detail what we are trying to accomplish, we need to get the attention of the audience. Depending on objectives, this may be any audience that comes along--or a very specific audience, such as Mrs. Connolly's seventh graders or perhaps opinion leaders and policy makers.

An obvious first step in gaining attention is to present our story where the people are. Yet this is not always done. For example, visitor centers are sometimes built out of sight of or even miles from heavily traveled roads.

Sometimes presentations are given where visitors will not stop or notice them. For example, at the Marine Science Center in Oregon, excellent exhibits are often ignored because they are on walls behind visitors who are watching the live fish. To reach people, information must be offered at the right times and places to be easily noticed.

Introductory Techniques

A number of introductory techniques are useful for gaining attention (Boulanger and Smith 1973). One is to offer valuable knowledge or skills. For example, a presentation might begin with: "What would you do if, while hiking, you found the trail blocked by a bear with two cubs?" Or it might begin with a discrepant or seemingly self-contradictory statement that arouses curiosity and requires explanation. For example: "This forest was created by a forest fire", or "The nearest formation of rock like this boulder is over 50 miles away". TV ads are full of discrepant events used for attacting attention.

Making Material Interesting

To hold attention, a presentation must be interesting. Interest depends on both the subject matter and the way it is presented. One study of exhibits showed higher visitor interest in violence and violent events than any other subject category (Washburne and Wagar 1972). This is nothing new. Plays and myths dating back thousands of years show that storytellers and entertainers have probably always known that violence is interesting. Fortunately, natural environments abound in violent stories that can be told in a tasteful way.

Although such subject categories as violence, animals, and ecological relationships are predictably interesting, the pattern of presentation is often more important than the specific subject matter.

Audience Benefit/Cost Ratios

For greatest effectiveness, communication and interpretation must have a good payoff and minimum hardship for the intended audience. In other words, to pay attention, the audience needs a good benefit/cost ratio. We must think about payoffs in the audience's terms. Sometimes we become so obsessed with the payoff to the organization we serve that we overlook the payoff to the people we are trying to reach.

Rewards or payoffs can take many forms. For the visitor who is already motivated to want information, such information is rewarding all by itself. Other visitors need a much larger vehicle of entertainment with a much smaller load of information. For example, Disneyland's Journey Through Inner Space was developed on behalf of a corporation at enormous cost. Yet the visitor's experience of penetrating first a snowflake, then a molecular lattice, and even an atom within an ice crystal, is almost pure entertainment. Toward the end of the experience he is told only the name of the corporation, the fact that it is in the business of rearranging molecules, and that he may see a few of the company's products on the way out if he chooses.

In a study of four visitor centers, average visitor interest was highest for dynamic presentations that included such things as motion, recorded sound, and shifting lighting. In contrast, interest was lowest for inert presentations of mounted photos and written labels. Yet such flatwork exhibits are probably the commonest of all. The contrast between dynamic and inert is also very close to the contrast between the media used for entertainment (usually rewarding) and those used for education (often uncomfortable) (Travers 1967, Washburne and Wagar 1972).

Psychologists have found that getting the right answer to a question is rewarding (Deterline 1962). This is the basis for teaching machines and programmed instruction. As one application of this, we developed a programmed nature trail in which visitors were asked a question at the bottom of each sign and then were given the right answer on the next sign. Children remembered more from these question-and-answer signs than from the usual signs.

One of the most rewarding things is simply having an effect when you do something. One study used a recording quizboard on which visitors answered four questions by pushing buttons (Wagar 1972). Each time a correct button was pushed, a "correct answer" panel lighted up and the visitor was presented with the next question. The quizboard--the only exhibit in the building that could be manipulated--became a favorite exhibit for children the moment we installed it.

The rewards of interpretation may be appropriate ends in themselves. But if rewards are intended as means of increasing understanding, they must be used carefully so that they help rather than hinder. For example, at the Chicago Museum of Science and Industry, most of the exhibits provide for visitor participation. But the day I visited, school groups were running about almost randomly twisting knobs, pushing buttons, and yanking handles but paying little attention to content. For the best learning we must make rewards contingent on such learning.

Persuading the Audience

When communication is designed to persuade, several principles are important (Dick et al. 1974). First, people are the most receptive to messages from sources or speakers they consider credible (i.e., trustworthy, intelligent, well-informed). Persuasion increases if the speaker first says something people in the audience agree with on some matter of importance to them. Greatest persuasion results when the audience is led to a new opinion in a series of small steps rather than a few big ones. For greatest persuasion, a message must not only arouse needs in the audience but also must provide a means for meeting such needs. When the audience will be exposed to contrary arguments, presentations that give both sides are the most persuasive. Finally, after people have been persuaded, discussion with others who have also been persuaded tends to prevent backsliding to the original opinion.

Making It Easy

As mentioned, the effectiveness of communication depends on costs to the intended audience as well as rewards. We can make our communication procedures easy on people by using familiar words and examples, avoiding difficult reading materials, tailoring presentations to the audience, and providing messages with a meaningful structure.

Word usage is important. Language is simply a signal system using symbols that have agreed-upon meanings among a specific group of people. Words are symbols, and full meanings really grow out of people's experiences. For example, do you recall specific places and events when reading the words "the sudden tug of a fish taking the bait", or "skipping rocks across the smooth water", or "the trusting grip of a child's hand"? The memories triggered by words can provide thousands of times as much information as the words themselves. The most powerful words are those that tap the most widespread sets of similar memories and associations among your audience.

But interpreters must often communicate with people whose memories, thought processes, and word associations are quite different from theirs. The most effective interpreters are those with a knack for translating meanings from one system of symbols (often the scientist's) into another (the visitor's). For example, at the Forestry Commission's Mays Wood Forestry Centre in England, the wood properties of different tree species are interpreted with wooden buckets, spoons, hockey sticks, etc. that visitors either have used or cannot understand how a geyser works unless they already know that the boiling point of water increases with pressure.

Structuring the Presentation

A final factor to consider in holding visitor attention is structure. Visitors need some sort of framework to make information fit together meaningfully. In a study of four visitor centers, visitors were more interested in holistic than fragmented presentations (Washburne and Wagar 1972). Thus exhibits that had parts making a whole story and that gave cause-and-effect relationships received greater visitor interest than exhibits that provided only isolated facts, such as the identification of species.

As another example of structure, Screven (1969, also personal communication 1970) found, in his studies at the Milwaukee Public Museum, that visitors who were given a pretest to find out what they knew before seeing an exhibit remembered more from the exhibit than visitors who received no pretest. Part of this increased recall may have occurred because the pretest warned visitors that they were part of a study. But the pretest also gave them an outline of things to look for. This suggests giving visitors an overview to orient them at the beginning of an interpretive presentation.

Orientation and focusing can also be provided within a presentation. One of the cassette tapes tested on a nature trail asked periodic questions of the visitor. This focused the visitor's attention and increased his retention of the information asked about. However, it decreased retention of information given just before and after a question.

At the Pacific Science Center, cartoon story lines are used to tie science stories together until youngsters learn enough concepts to handle a more scientific structure (Jerry Dotson, personal communication, 1970). The cartoon stories serve another useful purpose: The person giving a demonstration often asks youngsters what would happen if the cartoon character took a given action. If a youngster gives a wrong answer, it's the cartoon character's problem, not his own. This "projective" technique saves the child's ego enough that he'll go right on volunteering answers, right or wrong, without embarrassment.

Other methods of giving structure to a presentation include proceeding from the simple to the complex, proceeding from the whole to the parts, presenting a chronological development, progressing from the familiar to the unfamiliar, moving from the seen to the unseen, and showing increasingly broad application of a principle (Boulanger and Smith 1973).

EVALUATION

Having considered objectives and some ways of accomplishing them, we face the matter of evaluation or feedback to determine how well we are doing. In general terms, feedback is simply a set of signals indicating the extent to which an operation is going as planned and showing what corrective action would be useful. With good feedback, we can emphasize the things that work and improve our presentation, even when we are unsure of the exact reasons for improvements.

Much feedback is available informally, as interpreters watch their audiences, listen to questions asked, and look for other evidence of interest, enjoyment, puzzlement, etc. Such feedback is a major advantage of person-to-person presentations. However, enough visitors will compliment a bad presentation that informal feedback can be misleading as well as helpful.

Strangely, when interpreters substitute formal for informal person-to-person feedback, they usually focus on the speaker or the presentation. However, the effects we strive to achieve can only be observed in the audience.

To avoid questionnaires or interviews that tend to make every evaluation a research undertaking rather than a simple management effort, observational techniques can be used. One technique is simply to observe an audience at 1- or 2-minute intervals to see what percentage of people are watching the speaker or the presentation (Dick et al. 1975). In tests of the procedure, agreement between two observers was excellent (fig. 2). But differences both between and within presentations were striking. When the setting permitted, observers watched the eyes of members of the audience. With poor lighting or other conditions that made people's eyes difficult to see well, observers watched the directions people's heads were turned and found no appreciable loss in their ability to discriminate between high and low attention.

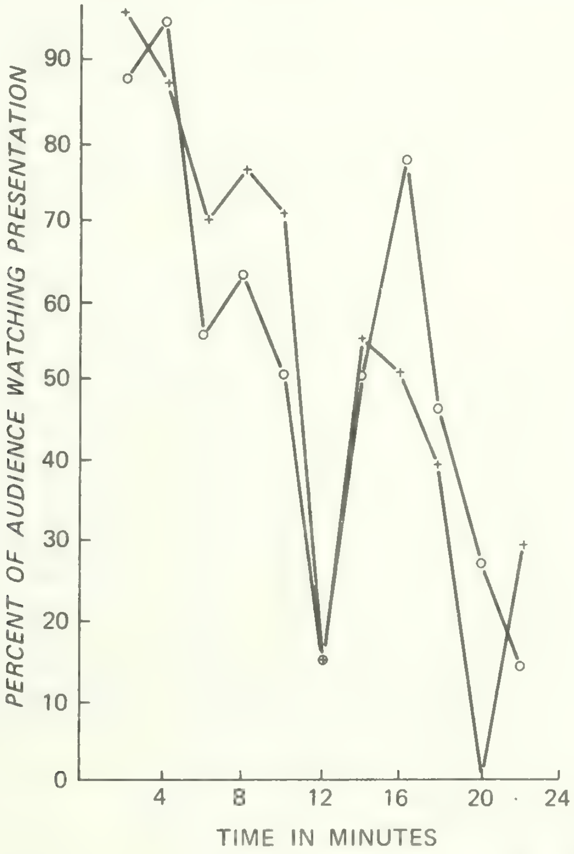

Figure 2.--A "candy-ecology" laboratory presentation. Energy flows among plants, grazers, and carnivores were simulated by the exchange of candy among people participating in the presentation. + = Observer 1. o = Observer 2.

Another feedback technique uses self-testing devices that record numbers of right and wrong answers. If we change a presentation and the percentage of correct responses goes up, the change was probably an improvement (Wagar 1972).

Ideally, a presentation should be improved before it is put in final form. Work at the Pacific Science Center to evaluate an energy exhibition while it was evolving showed that "quick and dirty" techniques are needed so that creative people get feedback immediately. Otherwise their great investment of energy and ego can make change quite painful. This decline inflexibility can occur in the few days it takes to summarize data from a more refined evaluation technique.

Six evaluation techniques were tested at the Pacific Science Center. Ranked on the basis of quick results and ease of application (table 1) they were: evaluation by a panel of judges, collecting comments in a suggestion box, observing what percentage of visitors paid close attention to a presentation, time-lapse photography, balloting by visitors, and having an observer unobtrusively follow sample visitors to determine how they were reacting.

Only evaluation by a panel of judges provided authoritative guidance during the early stages of a presentation's development. A checklist that focuses attention on objectives, the audience, and possibilities for improvement can help avoid inexpertness and preconceptions among available judges (fig. 3).

One additional phase of evaluation is to determine cost per visitor contact or perhaps some other unit of visitor participation. This requires records of both costs and attendance. A study of visitor contact facilities in the Black Hills National Forest showed a wide range of costs per contact. It also showed that nobody knew the cost per contact for various alternatives. Yet without this kind of information, cost effectiveness cannot be defined.

Evaluation of interpretive presentations probably will continue to be more art than science. A great amount of imprecise information can be obtained at little cost in time and money and with little burden on visitors. Given some understanding of the bias caused by visitors' desires to be congenial, the fact that people who visit interpretive programs and offer comments are self-selected, etc., managers of interpretive programs should be able to avoid the major pitfalls of using imprecise data. Many problems can be readily diagnosed from quite limited information. Nevertheless, managers must weigh the risks of using imprecise information against both the risks of nonevaluation and the costs of better data.

ACCEPTANCE AND APPLICATION

Acceptance and application of results from research on interpretation have been excellent. In fact, requests for publications, presentations, and consultation on interpretive matters have far outstripped the requests I have had for similar help based on research into recreational carrying capacity, recreation site management, estimation of visitor numbers, and visual management of forested landscapes. Our work to pull together interpretive principles and evaluation techniques has helped fill a void long recognized by interpreters. For several years research in interpretation was

Table 1.--Rating of six techniques for evaluating interpretive presentations

Technique	Speed of feedback	Burden on personnel	Cost for equipment and materials	Guarantee against bias	Usefulness and limitations
Opinion from selected outsiders (panel of judges)	Excellent	Small	Low	Low	Identifies major problems before public presentation
Volunteered comments (via suggestion box)	Good	Small	Low	Low	Can identify range of reactions; respondents self-selected.
Observed audience attention	Good	Moderate	Low	Good	Requires training. Assumes that "attention" indicates effectiveness. Respondent characteristics may differ at different presentations, making comparisons risky.
Time-lapse photography	Good	Small	Moderate to high	Good	Records continually, identifies use patterns, and captures infrequent occurrences with little burden on personnel. Area covered from one camera position usually quite limited.
Voting at individual presentations	Fair	Moderate to great	Moderate	Moderate	Respondent characteristics may differ at different presentations, making comparisons risky.
Following selected visitors	Good to fair	Great	Low	Good	Best for studying visitor orientation and movements. Inefficient for rating visitor interest in specific presentations.

CHECKLIST

1. OBJECTIVES:
    - a. From your observation of the interpretation, what do its objectives seem to be?
    - b. Are they reasonable?
    - c. (LATER) Are these the objectives outlined by the creators of the interpretation?
    - d. If not, why the discrepancy?
2. AUDIENCE:
    - a. In this setting, what are the likely objectives of the audience, and are the objectives of the interpretation compatible with the objectives of the audience or potential audience?
    - b. What proportion of the potential audience is stopping?
    - c. How long would it take the average visitor to fully experience this interpretation?
    - d. How long are visitors actually spending with this interpretation?
    - e. Do visitors seem interested or disinterested? Why?
    - f. Which age groups seem interested and which disinterested?
3. SETTING AND DESIGN:
    - a. Is it easy for visitors to reach or find this interpretation?
    - b. Is the visitor given sufficient clues to experience different elements or units of the interpretation in a meaningful sequence?
    - c. Is it easy and comfortable for the visitor to experience this interpretation? (Seating, if appropriate; suitable viewing available to children; etc.)
4. CONTENT AND DESIGN:
    - a. Is any of the information incorrect? Unclear? Inappropriate?
    - b. Do any conflicts occur within this interpretation or with nearby interpretation? (Consider competition for attention as well as conflicts in subject matter.)
    - c. What opportunities for improvement are available?
    - d. Why or how would these work better?

Figure 3.--Checklist for judging interpretation during its development.

carried out in close cooperation with personnel of the National Forest System and had their enthusiastic support. Also, in a survey of recreation managers and administrators in the South, 62 percent of the respondents rated "interpretation and understanding of forest and natural resource environments" as a top priority need (Task Force, 1974).

Many of our results from interpretive research have been used in training, not only by such agencies as the Forest Service and National Park Service but also in Africa and Latin America.

Like most other research, interpretive research is most likely to be applied if it is taken beyond mere proof that interesting relationships are probably significant (typically at .95 or higher probability). Although researchers still get most of their rewards for publishing such proofs, practitioners often need proven methodologies that have been worked out in some detail. Interpreters, however, have been unusually receptive to summaries of useful principles.

The primary barriers to conducting and applying research in interpretation are rooted in policies that reflect commodity-oriented land-use philosophies. (These policies are probably the major barrier for most forest recreation research.) Interpretation needs to be viewed as a vital part of resource management and, in the total mix of land use benefits, the enhanced experiences provided by interpretation need to be viewed as just as legitimate as traditional material products. This shift in philosophy and policy seems to be taking place, but agencies, like cultures, develop norms that remain stable for long periods and that can be changed only by overcoming great inertia.

The current bottleneck is in generating research results about interpretation, not in applying them. The Forest Service has been unable to continue its Environmental Interpretation Research Project. So far, although university researchers have contributed important studies, they have not mounted a sustained attack on interpretive problems. Such an effort might be stimulated by circulating the list of needed studies from a program analysis of Forest Service interpretation that is now in rough draft form in the Visitor Information Service (VIS) section of the Washington Office.

In conjunction with enlightened philosophies to guide land use policies, research in environmental interpretation can contribute greatly to the sustained flow of human benefits from our land resources.

KEY READINGS

Tilden, Freeman. 1967. Interpreting our heritage. 120 p. Chapel Hill: Univ. N. C. Press.
This sets forth an excellent philosophical framework for interpretation.

Sharpe, Grant W. (ed.) Interpreting the environment. N. Y.: John Wiley & Sons.
This is scheduled for publication early in 1976. With its emphasis on application it nicely complements Tilden.

Guideline. (A series of looseleaf sheets, part of "Park Practice Series")
See section entitled "Interpretation."

Trends. April/May/June 1974. Entire issue devoted to interpretation.
Both of these periodicals are published by the Park Practice Program, Washington, D.C.

Journal of Environmental Education. Contains many articles applicable to interpretation.

See also the following items under Literature Cited: Boulanger and Smith; Dick, McKee, and Wagar; Dick, Myklestad, and Wagar; Machlis and Field; Mager; Putney and Wagar; and Washburne and Wagar.

LITERATURE CITED

Boulanger, F. D., and Smith, J. P. 1973. Educational principles and techniques for interpreters. USDA For. Serv. Gen. Tech. Rep. PNW-9, 24 p. Pac. Northwest For. Range Exp. Stn., Portland, Ore.

Deterline, W. A. 1962. An introduction to programmed instruction. 131 p. Englewood Cliffs, New Jersey: Prentice-Hall.

Dick, R. E., McKee, D. T., and Wagar, J. A. 1974. A summary and annotated bibliography of communications principles. J. Environ. Educ. 5(4): 8-13.

Dick, R. E., Myklestad, E., and Wagar, J. A. 1975. Audience attention as a basis for evaluating interpretive presentations. USDA For. Serv. Res. Pap. PNW-198, 7 p. Pac. Northwest For. Range Exp. Stn., Portland, Ore.

Erskine, D. J. 1964. A-V materials in interpretive programs. Trends 1(1): 11-12.

Flesch, R. E. 1949. The art of readable writing. 237 p. N. Y.: Harper and Row.

Hunt, J. D., and Brown, P. J. 1971. Who can read our writing? J. Environ. Educ. 2(4): 27-29.

Machlis, G., and Field, D. R. 1974. Interpreting parks for kids: making it real. Trends. April/May/June: 19-25.

Mager, R. F. 1962. Preparing instructional objectives. 60 p. Belmont, Calif.: Fearon Publ.

Mahaffey, B. D. 1969. Relative effectiveness of visitor preference of three audio-visual media for interpretation of an historic area. 63 p. Dep. Inf. Rep. 1, Dep. Recreation & Parks, Texas A & M Univ., College Station.

McDonald, A. L. 1969. Final report to the National Park Service, Yellowstone Park. 35 p. Mimeo.

Oltremari, J. V. 1974. A survey on desirable preparation and career development of interpretive personnel. 158 p. Unpublished Master's thesis, Univ. Wash., Seattle.

Putney, A. D., and Wagar, J. A. 1973. Objectives and evaluation in interpretive planning. J. Environ. Educ. 5(1): 43-44.

Screven, C. G. 1969. The museum as a responsive learning environment. Mus. News 47(10): 7-10.

Shiner, J. W., and Shafer, E. L., Jr. 1975. How long do people look at and listen to forest-oriented exhibits? USDA For. Serv. Res. Pap. NE-325, 16 p. Northeast. For. Exp. Stn. Upper Darby, Pa.

Travers, R. M. W. 1967. Research and theory related to audio-visual information transmission. 287 p. U. S. Dep. Health, Educ. and Welfare. Washington, D.C.

Task Force on Forest Resources Research Needs for the Southern Region. 1974. Research needs in forest recreation, aesthetics, and other landscape values: RP 2.07. In Task force report, p. 61-105. USDA For. Serv., South. Reg.

Wagar, J. A. 1972. The recording quizboard: a device for evaluating interpretive services. 12 p. USDA For. Serv. Res. Pap. PNW-139. Pac. Northwest For. Range Exp. Stn., Portland, Ore.

Washburne, R. F., and Wagar, J. A. 1972. Evaluating visitor response to exhibit content. Curator 15(3): 248-254.

A CRITIQUE OF THE PAPER ENTITLED "ACHIEVING EFFECTIVENESS IN ENVIRONMENTAL INTERPRETATION" BY J. ALAN WAGAR

Ronald D. Johnson[1]

Wagar's paper is an excellent one for land managers and interpreters. It presents very succinctly a rather typical overview of the scope of the interpretive function. Research reviewed provides managers and interpreters with guidelines and ideas to improve upon or to provide initial interpretive service.

One of the significant findings reported by Wagar related to the practice of selecting interpreters. Perhaps too often emphasis is on technical knowledge or training, experience and ability of the interpreter to communicate. This selection practice, the relative absence of career ladders reported, and findings which point out other discrepancies and deficiencies should not be viewed as generators of adverse reactions to the state-of-the-art of interpretation, nor cause criticism of personnel or services evaluated. Instead, it is proposed that research results, informal evaluations, and judgments disclosing weaknesses of this yet developing element of resource management - interpretation and interpretive recreation - be viewed in a manner which will allow an expanded perception of the state-of-the-art and provide a key to further developments.

In spite of the availability of several significant works, the body of knowledge related to interpretation appears to be relatively scanty. It is desirable that research results be published or broadly disseminated to practitioners in a manner which will popularize this important work.

The research itself must be broadened. In addition to identification of constraints, it is desirable that interpretive elements be discovered which will contribute significantly to the sustained flow of resource benefits.

We must tag on to developments in other disciplines as well, looking for the generic core which can be applied. Policy analysis can be "scientific." Admittedly, it is difficult for a control group and politicians to accept placebos if they have knowledge of expanded services to other constituents. Evaluative research can be employed; like other research, it can also be expensive.

On the other hand, we must shortly begin to identify and accept principles of environmental interpretation and resist funding replications of earlier "research", particularly in "environmental education". There is too much that is new to discover.

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[1] Director of Parks and Recreation, North Carolina Department of Natural and Economic Resources, Raleigh, North Carolina.

Eventually, the electorate will make land use decisions, and already are, o an extent, through elected representatives and referenda. Our perspectives f scope of responsibility must be broadened. We have been dealing too much n ego-serving activities, "doing our own thing" in the out-of-doors, too ften entertaining without much carry-over resulting, directing our energies o the one percent or three percent who "enjoy nature." Justification is eeded to attract the attention of the masses; growing problems of land use ay provide the vehicle.

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What is the satisfying recreational experience? To whom?

What results are desired?

Will interpretation of the natural history yield more positive results hen tied to the cultural heritage and practices?

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ECONOMICS APPLIED TO OUTDOOR RECREATION: AN EVALUATION

Frank J. Convery[1]

Abstract.-- The uses and limitations of economics for outdoor recreation planners and managers are discussed. Special attention is devoted to the estimation of costs and benefits of providing outdoor recreation, and the extent to which such estimating procedures can be used by field personnel.

INTRODUCTION

The evaluation of outdoor recreation benefits is a much discussed, if still poorly understood topic. I propose to examine this issue in the larger context of the present and potential role of economics in outdoor recreation management and planning. The central concept of economics-choice-and what its acceptance implies, is first introduced. Then the derivation and use of cost and benefit estimates are successively discussed. Representative examples of pertinent research are cited, while the relevance and accessibility of such work to recreation planners and managers are concerns which pervade throughout.

ECONOMICS AS THE STUDY OF CHOICE

Economics is concerned with the study of choice. This implies that for economics to be useful as a management-planning tool, choice must indeed exist, both in fiscal-institutional-political terms, and in the mind of the manager. There seems to be a human propensity to unduly narrow the range of choices. As Henry Kissinger has observed:[2]

> "I have seen it happen more often than not that when one asks for choices one is always given three: two absurd ones and the preferred one. And the experienced bureaucrat, which I am slowly becoming, can usually tell the preferred one because it is almost always the one that is typed in the middle."

If the manager is irreversibly convinced that present procedure is the best that can possibly be done, economic analysis in any meaningful sense becomes redundant. If applied in such circumstances the results if appropriate, will likely be used to support present or already planned activity; if the results do not support the proposed action, they will be ignored. The potential for change, then, must exist, for economics to be useful. The economist asks questions such as these: What are the alternatives? Is there a less expensive means of accomplishing this objective? Can we generate more benefits out of this level of expenditure? and so on. Although most of us would no doubt claim to welcome and encourage the analyses that the asking of such questions imply, in fact we observe that these issues are not routinely raised in recreation planning. A number of reasons may be posited in explanation:

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[2] Quoted in the New York Times Magazine, October 28, 1973.

1. Managers are so preoccupied with operational considerations that time is not available to critically examine what is being done, and to consider what might be done. Opportunity and capacity for reflection on alternative modes of operation are clearly prerequisites for the application of economic analysis.

2. Identification and analysis of alternatives can threaten vested interests. Since, by the very nature of their discipline, economists are trained to ask, is there a better way?, they implicitly threaten those whose interests are served by present procedures. If for example, it is concluded on the basis of a rigorous analysis that a campground should be closed down, or that an activity could be more efficiently carried out by another department or agency, it seems likely that those individuals who would be adversely affected by this conclusion will be displeased with the analysis. In order to avoid situations of this sort, and the uncivilized necessity of beheading the bringer of bad tidings, there is a tendency to try to prevent the issuance of the message in the first place. Economics can, in short be a very subversive science, posing some risk to those affected by its results.

3. Some skill is required to identify pertinent alternatives and to undertake the analysis; skill is also required to interpret its results. Managers who lack the requisite capabilities may prefer to forego analysis entirely, so as to avoid the potential embarrassment of having decision-making prerogatives somewhat pre-empted by a set of procedures which they do not understand.

To summarize this section, it is concluded that a major--perhaps the major--precondition for the fruitful use of economic analysis in outdoor recreation management and planning is an appropriate mental attitude by the potential user--an enthusiasm for exploring alternatives matched by a willingness to take risks, expressed in such terms as loss of position or authority if the results of the analysis call for same. The appropriate attitude and the undertaking of economic analysis are mutually reinforcing. By this I mean that the proper application of economics will encourage further probing of alternatives, until eventually such a mind-set becomes second nature to the planner. This reinforcement of the questioning instinct is an important benefit of using economics. While alternatives assayed will usually fall within the realm of what is presently feasible, options which involve contravening current legislative, budget, institutional or other constraints should be considered. If such is not done, the desirability or otherwise of modifying these constraints cannot be evaluated. Thus, at the extreme, a recreation planner might explore the implications of modifying the homocide laws so that miscreants caught vandalizing recreation facilities could be put up against a wall and shot right away (an option which has some appeal for the author). More realistically, a mix of strategies involving restoration of some police powers to the rangers, higher fines, public education, large rewards for information leading to convictions, etc. could be examined.

Given an appropriate perspective by the potential user, to what extent can the technical intricacies of economics be readily applied in outdoor recreation planning? The art of the economist can be used to delineate the costs and benefits associated with various alternatives. A special sub-classification would include local and regional income and employment impacts and distribution effects. Each of the two elements--costs and benefits --will be discussed with a view to elucidating the state of the art regarding their estimation vis-a-vis outdoor recreation; the extent to which such information can be derived and appropriately interpreted by the recreation manager will be explored.

COSTS

Costs can be defined as the value of the good or service which is being given up (foregone) in order to undertake an action. The costs (and benefits) which are taken into consideration will depend on the perspective of the decision-maker involved. The private campground owner will count his cash outlays, together with an allowance for his own time and for depreciation of the facilities. State and local government campground administrators will include outlays from the government treasury in question; outlays which are financed by another level of government e.g. federal, state (in case of local govt.) will not be included as costs. Governments at this level will also be concerned with other costs; the disruptive effects of a recreation area on a local community, the damage to a fragile ecosystem, reduction of habitat for rare and endangered species comprise examples of this type of cost. The federal government is concerned with the welfare of the whole society, so that costs from this perspective will include all of what is being foregone by the various members of society in order to provide the recreation in question. Identification and measurement of costs at the Federal level represent the acme of complexity. Such costs can be placed in three categories:

(1) Direct input costs: Included here are costs of land, physical facilities, labor, etc. These should be valued at the welfare foregone by society in order to use the inputs for producing recreation opportunities. Since societal welfare cannot be measured, we substitute "value of output" foregone for welfare foregone; the cost of producing recreation is the value of the output foregone elsewhere in order to do so. In a full employment competitive economy, the price of the inputs at the margin represents their full social cost; if persons are hired at $100/week to supervise a campground, these individuals must be attracted away from other activities where their marginal products (contribution to output) are approximately equal to their respective wages. Likewise, under these conditions the price of other inputs will represent their full social cost. However, during periods of persistent unemployment some factors can be used in outdoor recreation activities without reducing output elsewhere in the economy; the price paid for such inputs will likely overstate the social cost of their use. Economists have developed algorithms for deriving the appropriate social costs--called shadow prices--of inputs (Haveman and Krutilla, 1968).

Even in a competitive, full employment economy, there may be conditions where price of all of the inputs does not identify all of the cost categories involved in producing outdoor recreation opportunities. Such conditions arise where external costs (externalities) exist. External costs are defined as costs which are external to, that is to say, not incurred exclusively by, the producer. They can be divided into two groups--environmental and social--and these comprise the remaining cost categories discussed in this paper.

(2) Environmental Costs: Environment is here used in the sense of the bio-physical environment. Costs of this nature include the elimination of species (Krutilla, 1967), the pollution of air and water, the despoilation of landscape, the termination in perpetuity of opportunities to enjoy an irreplacable and unique environment, and so on. These costs represent several

facets of foregone benefits--the downstream water user is deprived of clean water, future generations are deprived of the medicinal properties of the extinct plant, etc.

(3) Social Costs: These include adverse affects impinging on individuals and groups which are not included in (1) and (2) above. Such costs would include the damaging or destruction of a culture, such as the debilitation of the Indian cultures resultant from the Caucasian settlement of North America. Likewise damage or elimination of archaeological remains would be included in this group. Congestion costs--the costs recreation users impose on each other by their mutual presence in an area or facility are also costs of this type.

It has proved much easier to derive direct input costs in a common unit of value--dollars--than it has to quantify the environmental and social costs. These latter cost categories are commonly introduced as constraints--leave a buffer strip x feet wide to prevent stream sedimentation, preserve all archaeological mounds, and so on. The analyst can, however, assay the cost at which these constraints are maintained by successively relaxing them and observing the resulting change in net benefit.

The literature relating to the estimation of costs involved in the provision of outdoor recreation is surprisingly sparse. Beardsley, Schweitzer and Ljungre (1974) provide an interesting taxonomy of cost categories relating to the provision of wilderness recreation. Tyre (1975) presents average cost estimates for the provision of various outdoor recreation experiences on National Forests in the South. He uses the following formulation:

$$AC = [OM + C + O_1 + O_2 + OH]/RVD$$

Where:

AC = Average Cost
OM = Annual Operation and Maintenance
C = Construction (annualized)
O_1 = Foregone opportunity to harvest present timber stocking (annualized)
O_2 = Foregone opportunity to accumulate annual timber growth for harvest (annualized)
OH = Annual Overhead
RVD = Annual recreation visitor day (12 hours) use.

Lundgren (1974) provides a similar (hypothetical) example of the derivation of average cost of providing camping on a national forest in the Lake States. The Tyre-Lundgren estimates embrace only direct input costs. In addition to estimating average cost (Total Cost/Total Use), it is also helpful to derive marginal cost (incremental cost/incremental use). This tells the planner what the additional cost per unit of added use will be as a result of extending capacity, e.g. enlarging a campground, extending a trail, etc.

$$MC \text{ (Marginal Cost)} = \Delta \text{ Total Cost}/ \Delta \text{ Anticipated Use}$$

As we have seen, average and marginal cost information is fairly straightforward to derive for direct inputs. Every recreation planner should know how much various types of recreation use are presently costing per unit (average cost) within his or her jurisdiction and how much it would cost per unit to increase use (marginal cost) in these terms. Identifying environmental and social costs is much more complex. However, there will be instances where the choices are essentially invariant as to these types of cost, in which case direct input costs information assumes special significance. This will often be the case when environmental costs are represented in the form of constraints emanating from a higher administrative level.

BENEFITS

Just as a reduction in welfare (cost) cannot be adequately calibrated, likewise a welfare increase cannot be so measured. Once more, an increase in welfare is approximated by an increase in output of goods or services; such increases are valued by what individuals are willing to pay for them, which may or may not correspond to what is actually being paid. The symmetry between cost and benefit measurement should be noted: costs are measured by what we are willing to forego in order to appropriate the input(s) to the use(s) in question; benefits are measured by what we are willing to forego in order to appropriate the output(s) to the use(s) in question. Thus when two mutually exclusive uses are being compared for an area of land, the cost of using it in one use is the net benefit foregone by not using it in the other.

Most of the outdoor recreation economics literature is concerned with methods for valuing benefits. Knetsch and Davis (1966) identify the following recreation valuation methods:

(1) Gross Expenditures Method: Measures value to the user by the total amount spent on recreation. The concern in this paper is to help the recreation resource manager make better decisions. The entity of interest therefore is what individuals of the facility are willing to pay for admittance above and beyond what they incur for related items such as food, lodging, transportation and equipment, i.e. the value accruing to the resource is a residual value, just as a cinema owner is primarily concerned with what individuals are willing to pay for admittance, not what they spend on travel, food, etc. en route. Thus, while it is recognized that gross expenditures estimates will be of considerable interest and use to various segments of the recreation industry, they are not directly pertinent to the issue of managing an outdoor recreation resource.

(2) Market Value of Fish or Game: Imputes to hunting and fishing recreation the value of the game and fish caught. The hunter or fisherman should be willing to pay at least up to the expected value of the fish or game caught. For many sportsmen the expected value of the catch is but a minor portion of the utility deriving from this day's sport. Also, for many fish and game related recreation activities, such as nature photography and hiking, there is no fish or game harvest. Still, for certain types of hunting and fishing activity, this method does provide minimum value estimates.

(3) Market Value: Recreation benefits are valued by what people actually pay at the resource level for the experience. This of course is the primary measure of benefit used by private sector purveyors of outdoor recreation. The same tendency towards increase in complexity of the valuation process which

was observed in the discussion on cost estimation as one goes from the private sector through successively higher levels of government, also pertains to benefits. This results because of the existence of external benefits which presumably are a more prominent feature of recreation outputs on public lands. External benefits can be defined as benefits resulting from the provision of outdoor recreation which cannot be "captured" by the provider. Thus, if, as is sometimes claimed, camping makes individuals more contented, congenial and well adjusted and less apt to commit crime, the three dollar nightly camping fee charged will understate the social benefit of the experience. A limiting case of an external benefit is a public good, defined as a good, such as national defense or clean air, which, if made available to one person is automatically available to all.

Following the convention adopted in the case of costs, external benefits can be classified as environmental or social. Environmental benefits are the mirror image of the environmental costs discussed earlier: examples include the benefits of retaining habitat for plants and animals; the value to passersby of an aesthetically pleasing landscape; non-user benefits such as those accruing to individuals who derive satisfaction from simply knowing rare or remarkable areas or species exist, or to individuals who value the option of experiencing the environment in the future--option demanders. The retention of genetic information consequent on the preservation of species is another non-user public goods type of external benefit. Social benefits include reduction in crime and medical expenses, increased job productivity etc. resulting from the recreation experience(s). Favorable cultural, archaeological and other impacts would likewise be included in this category. Recreation benefits then can be classified as direct--those accruing entirely to the user, or external, sub-classified for expository purposes in this paper as environmental and social. In the instances where external benefits exist, the aggregate willingness to pay of users will understate total benefits generated. For a variety of political, institutional and cultural reasons, governments have generally not imposed a charge for outdoor recreation sufficient to cover costs of its provision. When there are no external benefits involved, this connotes a transfer payment from non users to users. If one particular group, e.g. the middle class are the principal users of a state's outdoor recreation facilities, the state government may feel that this group does not get its "fair share" of other state provided services, and this recreation subsidy is a means of compensation. At the Federal level, if congressional appropriations are related somehow to number of visitors, the U. S. Forest Service, U. S. Park Service, and Army Corps of Engineers may not wish to unilaterally raise fees, thereby reducing the number of visitors and their share of the Federal "pie." It may simply be prohibitively expensive to collect fees, or, if the additional cost associated with an additional visitor is very low, a decision could rationally be made to maximize social welfare by setting price equal to the (very low) marginal cost, even though this resulted in total revenues less than total costs. For these and other reasons too numerous to detail here, price of government provided outdoor recreation rarely renders an acceptable estimate of its direct user benefits, ignoring for the moment the external benefits which may also be generated. Economists have had some success in developing user willingness to pay estimates, the next category of benefit estimating procedures to be examined.

(4) Willingness to Pay Methods.[1] These methods purport to estimate the willingness to pay by consumers for outdoor recreation at the resource level, i.e. willingness to pay in excess of outlays for travel, lodging, etc. As such, if the estimates yielded were reasonably accurate, very worthwhile information would be provided to the recreation resource planner. Two valuation approaches have been developed:

(a) Interview Approach: In this method, each consumer is involved in a bidding game. Bids are systematically raised until the user declares himself excluded. This amount represents this individual's maximum "willingness to pay" for the experience. Summing these values for all consumers yields an aggregate maximum willingness to pay. The principal problem with this approach is the degree of reliability which can be attached to the information which the respondents provide. They may not be able to relate to the question(s) at all. Even if they can, if they think that the information will be used as the basis for charging for the recreation experience, there will be an incentive to understate; if on the other hand they feel that the information will help keep the area in its present use, the incentive will be in the opposite direction. A careful study by Robert K. Davis, valuing recreation use in the Maine woods, reported in Knetsch and Davis (1966) provides a good example of this approach. More recently the Environmental Research Group (1973) at Georgia State University undertook a very extensive household survey throughout the Southeast to elicit willingness to pay estimates for wildlife related recreation. However, difficulties of interpretation arose concerning these data as originally published; clarifications regarding what precisely was being measured, together with bridging material relating the method and results to the appropriate theoretical constructs in welfare economics are now in preparation.[2]

(b) Travel Cost Method: The basic idea underlying this H-C-K approach[3] is that increased access costs will tend to affect visitation in the same way as increased user charges. By observing the response to changes in the cost of access, we can impute the response to changes in the admission fee, and thereby derive the demand curve for the area in question. The area under the demand curve up to the quantity actually consumed yields the aggregate willingness to pay per unit time for the site(s). In addition to access costs, most applications of this algorithm include demand shifters such as income and influence of competing sites. It is implicit in this approach that the trip taken is a single purpose trip, and that travel time has neither positive nor negative value. These and other limitations, together with methods for overcoming them or mitigating their effects are discussed by Beardsley (1971). This author feels that the travel cost approach should yield more reliable estimates than the interview method, because the former is based on actual rather than hypothetical behavior. Economists generally seem to feel that, if undertaken with skill and care and with assumptions clearly spelled out, the travel cost approach yields results which are imperfect but which are defensible as measures of user benefits from outdoor recreation. To what extent has this work been applied in the field?

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[1] These methods, and several other aspects of recreation economics are discussed very thoroughly by Kalter (1971), and Knetsch (1974).

[2] Personal verbal communication. Joseph C. Horvath, School of Forestry, U. of Montana.

[3] So called because the idea was first introduced by Hotelling (1949) and then developed by Clawson and Knetsch (1966).

A survey by the author of state recreation departments in the Southeast indicated that none of them attempt to place a value on the recreation experiences they provide. At the federal level some desultory use of the range of values recommended by the Water Resources Council (1973)[1/] is in evidence, but no sustained coordinated effort to derive "willingness to pay" values has been undertaken, to the author's knowledge. However, an excellent evaluation of reservoir recreation in Texas has been completed by Grubb and Goodwin (1971) for use in the Texas Water Plan, using an elaboration of the H-C-K method, and many other worthwhile ad hoc studies have been completed.

Another recent survey undertaken by the author indicates that the cost of implementing the willingness to pay valuation approaches ranges from $5,000 to $300,000 depending on the scope and complexity of the analysis. These are not large outlays when compared to the potential investment and quantity of output at issue. However, in addition to financial resources, a fairly high degree of technical skill is required to undertake such work and to interpret the results. Work of this nature is best undertaken at a regional level: data can be gathered most efficiently, avoiding costly duplication, a likely comcomitant of a project by project approach. Between-site interactions can be captured, and the requisite skills can be applied most efficiently. The field planner or manager will likely have difficulty deriving and using willingness to pay values if, in this respect, he is operating in an institutional vacuum. Instead of attempting to predict recreation use at a range of prices for a proposed plan or site--i.e. to derive the site demand curve--the planner can assume the present price range will obtain throughout the planning horizon. By getting a sense of the distance people are prepared to travel for recreation of the type in question, together with population and income projections for the localities defined by this travelling distance,[2/] and present rates of participation, some sense of potential consumption can be derived. This can be matched against present and potential capacity. If consumption will exceed capacity under these conditions, various rationing

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[1/] A value range of $0.75 - 2.25 per recreation day is recommended for general, ubiquitous recreation such as camping, warm water fishing and small game hunting. A range of $3.00 - 9.00 is recommended for specialized recreation, including wilderness camping and big game hunting.

[2/] Such small area projections are available from the Water Resources Council.

schemes such as raising price, instituting a first-come first-served permit system etc. can be examined; the possibility of expanding capacity can be explored, this being viewed in the context of what must be compromised elsewhere to achieve such expansion, and so on.

If the valuation of direct (user) recreation benefits is deficient in theory and practice, the equivalent process for external benefits has barely even begun. However, Krutilla and Fisher (1975) in their excellent book The Economics of Natural Environments point out that often it is not necessary to arrive even at direct benefit values for non-development use of natural areas. They identify, using time series data, an asymmetry in the valuation of the benefit stream resulting from development of natural resources as compared to the benefit stream resulting from leaving them in their natural state. They argue that the real price of the development alternative tends to fall over time as a result of technological development, while conversely the price of outputs from the non-development option is likely to rise since there are no close substitutes, supply is essentially fixed or declining, and such outputs appear to be quite income elastic. They demonstrate in a number of case studies that if the appropriate decay function is introduced in the development alternative, it has negative net benefits; the preservation alternative emerges by default as it were, as the best choice--the need for valuation of preservation benefits does not arise.

With some trepidation the following steps are recommended for the recreation manager regarding benefit estimation:

(a) Find out what is actually being paid presently in your locality for various recreation experiences comparable to those to be offered at the facility or area for which you are planning.

(b) Estimate the expected value of fish or game caught per visitor day.

(a) and (b) should give you a feeling for what the minimum values might be that you could apply to the proposed outputs. This last expression--proposed outputs--is a rather slippery concept, since the recreation actually consumed will depend in part on what is charged for it.

(c) Estimate future consumption along the lines discussed earlier in the text.

(d) If the choices are very contentious, as when an area suitable for wilderness designation also has valuable commodity resources, try to hire a competent applied welfare economist to help derive willingness to pay estimates.

(e) Encourage higher echelon personnel to devote resources to the development of willingness to pay estimates for recreation.

(f) Try to pinpoint and discuss external benefits emanating from the proposed recreation plan(s).

CONCLUDING REMARKS

It was suggested that a major advantage of using economic analysis in recreation planning is that it institutionalizes the consideration of alternatives. Prerequisites for fruitful use of economics include a positive attitude toward potential charge, sufficient time for and a capacity for reflection, and a capability to use and understand the analytic techniques. The manner in which economists set about identifying the costs and benefits associated with particular recreation plans was discussed. Two broad categories of cost and benefit--direct and external--were identified. It was concluded that in most instances direct costs (average and marginal) could be fairly readily derived by the recreation manager.[1/] Such information could be used to help guide pricing policy.[2/] Knowing the direct cost at which recreation of various types is being and can be generated can be very helpful to a decisionmaker, even when the value of benefits generated in each instance has not been determined. Being able to examine the cost implications of implementing alternative means of reaching a predetermined objective can also be helpful. Among other things it may result in a re-appraisal as to whether that particular goal should indeed be "pre-determined." Except in the case of recreation provided by the private sector, and here by no means always, price paid does not usually yield a good measure of the direct (user) benefit of a recreation experience. A substantial research effort has been undertaken over the years to develop and refine methods for deriving such benefit values. The "willingness to pay" valuation approaches appear most appropriate, but their adoption by the major outdoor recreation providing agencies has been only sporadic. Until a more positive attitude on this matter is taken by the agencies, there is little the individual site planner can do in this regard, unless he or she happens to have skills in recreation economics and have the time to indulge them. Failing this, undertaking careful use projections under various scenarios, and displaying how much it will cost (direct) to accommodate various posited levels of consumption is a useful way to link use and resource requirements.

Efforts should be made to identify and discuss external costs and benefits. The implications of taking a significant irreversible decision (all decisions being irreversible in a trivial sense) should be spelled out with particular care. In some instances it will not be possible to classify an externality as either a cost or benefit, since its "value" will depend both on the perception of the individual and on the context in which it would occur. Thus the development of tourism in the Appalachians will be viewed by one person as a means of providing employment, thus retaining economic and thereby cultural viability in the mountains, while another will view the same proposal as emasculating and debilitating, likely to remove the last vestiges of individuality and dignity from the group in question. Economists have had some success at tracing the local income, employment and tax yield impacts of alternative levels of outdoor

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[1/] However, there may be difficulty in allocating some costs in the case of multi-output projects. However, reasonably satisfactory procedures have been developed for handling such situations. See Eckstein (1965) for a discussion of these.

[2/] Several articles in the Journal of Leisure Research 7(2), 1975 discuss recreation pricing policy.

recreation use. To a somewhat lesser degree, the distribution of benefits and costs--who gains and who loses, and to what extent--has also been examined.[1] Such impacts can only be displayed, since their positive or negative significance will depend on perspective and context.

Thomas Carlyle admonished economists in 1850:

> "Professors of the Dismal Science, I perceive that the length of your tether is now pretty well run; and that I must request you to talk a little lower in the future."

This refrain is frequently echoed today. I hope that this paper gives some small flavor of the more positive aspects of the Dismal Science as it relates to outdoor recreation.

LITERATURE CITED

Beardsley, Wendell, Dennis Schweitzer and Douglas Ljungre. 1974. Measuring Economic Costs of Wilderness Land Allocation. Paper presented at A National Symposium on the Economics of Outdoor Recreation, New Orleans, La. November 11-13, 1974 (Proceedings forthcoming from USDA Forest Service).

Beardsley, Wendell. 1971. Bias and Noncomparability in Recreation Evaluation Models. Land Economics 47:175-180.

Clawson, Marion and Jack L. Knetsch. 1966. The Economics of Outdoor Recreation, Baltimore, Johns Hopkins Press.

Eckstein, Otto. 1965. Water Resources Development; the Economics of Project Evaluation. 300 p. Cambridge, Harvard University Press.

Environmental Research Group. 1973. Southeastern Economic Survey of Wildlife Recreation. Atlanta, Georgia State University.

Grubb, Herbert W. and James T. Goodwin. 1971. Economic Evaluation of Water-Oriented Recreation in the Preliminary Texas Water Plan. Report No. 84. Austin, Texas Water Development Board.

Haveman, Robert H. and John V. Krutilla. 1968. Unemployment, Idle Capacity, and the Evaluation of Public Expenditures: National and Regional Analyses. Baltimore: Johns Hopkins Press.

Hotelling, Harold. 1949. Letter in The Economics of Public Recreation, Washington, D. C. Land and Recreation Planning Division, National Park Service.

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[1] Some literature relating to regional impacts and distributional effects vis-a-vis outdoor recreation is reviewed by Kalter, op.cit. p. 127-172.

Kalter, Robert J. 1971. The Economics of Water-Based Outdoor Recreation: A Survey and Critique of Recent Developments. 192 p. Springfield, Va. National Technical Information Service, U. S. Department of Commerce.

Knetsch, Jack L. 1974. Outdoor Recreation and Water Resources Planning. Water Resources Monograph 3. 121 p. Washington, D. C., American Geophysical Union.

Knetsch, Jack L. and Robert K. Davis. 1966. Comparison of Methods for Recreation Evaluation in A. V. Kneese and S. C. Smith (eds.) Water Research p. 125-142. Baltimore: Johns Hopkins Press.

Krutilla, John V. and Anthony C. Fisher. 1975. The Economics of Natural Environments. 292 p. Baltimore, Johns Hopkins Press.

Krutilla, John V. 1967. Conservation Reconsidered, American Economic Review 57:777-786.

Lundgren, Allen L. 1974. Economic Bases for Allocating Resources in Outdoor Recreation. Outdoor Recreation Research: Applying the Results. USDA Forest Serv. Gen. Tech. Rep. NC-9, 113 p. North Cent. For. Exp. Sta., St. Paul, Minn.

Tyre, Gary L. 1975. Average Costs of Recreation on National Forests in the South. Journal of Leisure Research 7:114-120.

Water Resources Council. 1973. Water and Related Land Resources: Establishment of Principles and Standards for Planning. Federal Register 38: Part III September 10.

A CRITIQUE OF THE PAPER ENTITLED "ECONOMICS APPLIED TO OUTDOOR RECREATION: AN EVALUATION"

G. Robert Olson[1]

There are two major questions posed in the "Introduction" to this paper, i.e., (1) what are the present and potential roles of economics in outdoor recreation management and planning, and (2) what economic research is relevant and/or accessible to recreation managers and planners?

The major portion of the paper is a response to the first question consisting of a discussion of the concepts and methodologies of recreation benefits and costs, and the arguments on their strengths, weaknesses, and applicability are well presented. The second question, however, begs to be answered.

After bemoaning the fact that unless the manager maintains an open mind concerning alternatives, economic analysis becomes redundant; Convery reveals the root of the problem in listing questions "The economist asks. . . What are the alternatives? Is there a less expensive means of accomplishing this objective? Can we generate more benefits out of this level of expenditure? and so on." In terms of generating economic analysis which is both useful to and usable by managers, the questions which are perceived as relevant to managers are not those the economist asks, rather those the manager asks. Recreation planners and managers are typically concerned with such questions as "How many picnic tables should be built?", "What mix of facilities should be constructed on a given site?", and "What will be the effect of the fuel crisis on recreation visitation?" Granted the possibility that some of the questions asked by both could and/or should be the same, I would agree that often this is not the case for some of the same reasons listed by Convery. In addition, I would argue that many recreation managers' experiences with economists and economic analysis have been limited to presentations by economists on a theoretical/conceptual level rather than an immediate problem solving level and that when the concepts have in fact been applied to on the ground problems, the results and implications of the work have not been effectively communicated to the manager, ergo the Dismal Science.

This is not to suggest that the lack of communication is a one-way affair. LaPage (1974) has suggested that the word "'demand' sums up a world of misunderstanding" between economists and recreation administrators. He explains thus:

> For the economist, "demand" is a concept of simple elegance and almost unlimited utility. For the recreation manager, "demand" is that less than elegant, but equally unlimited, horde knocking down the gate.

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It is further suggested that "market analysis" provides a middle ground "where economic theory and the realities of administration can meet and where both economists and managers can find useful answers to their questions." LaPage goes on to say the questions usually heard from park managers "are not questions of 'how much recreation at what price?,' they are questions of 'what kinds of recreation and for how long?'"

Recreation researchers in general and economists in particular must take the initiative in establishing effective communications with recreation managers and planners to determine what problems are perceived as relevant so that research and analysis can be oriented to those areas. Only through such efforts will managers and planners gain an appreciation for the potential power and relevance of the discipline as it relates to outdoor recreation.

LITERATURE CITED

LaPage, W. F. 1974. Market Analysis for Recreation Managers (and Down to Earth Economists). Paper presented at Economics of Outdoor Recreation, A National Symposium, New Orleans, Louisiana. November 11-13, 1974 (Draft, Proceedings forthcoming from USDA, Forest Service).

PRINCIPLES OF RECREATIONAL CARRYING CAPACITY

David W. Lime[1]

Abstract.--Recreational carrying capacity is a complex and troublesome concept that incorporates principles of the social as well as the physical and biological sciences. There is no magic number that is the capacity for a given recreation site. Deciding how much and what kind of use is acceptable for an area must be based on managerial judgement and experience. The uncertainty of such decisions can be substantially reduced by a consideration of the interrelationships of (1) management objectives, (2) recreation user attitudes, and (3) impacts of recreation use on natural resources. Some basic principles, based on a review of the current state-of-the-knowledge, that relate to carrying capacity and that seem relevant to outdoor recreation management are discussed.

Additional keywords: Management objectives, user attitudes, resource impacts, managerial judgement, regional planning, and use control techniques.

Recreation planners and administrators are increasingly being challenged to manage the growing numbers of outdoor recreationists. Many areas, both public and private, are being threatened by overuse. For some managers the situation is reaching crisis proportions--the physical environment is being damaged beyond acceptable limits and the people visiting these areas are no longer receiving a quality or enjoyable outdoor experience.

Determining Recreational Carrying Capacity is frequently voiced as a manager's answer for solving the problem of seemingly overused recreation areas. In defining carrying capacity, I assume that the primary goal of recreation management is to provide enjoyment and benefits for people. There are certain constraints in doing this, of course--budgetary, administrative, legal, and the capabilities of the physical environment. Thus, managers must determine the amount and character of use an area can sustain over a specified time period without causing unacceptable change to the physical environment or to the experience of the user.

Deciding what constitutes unacceptable change is fundamental to the capacity concept. Numerous students of the capacity issue have identified the interrelationships of (1) management objectives, (2) visitor attitudes and perceptions, and (3) impacts of recreation use on the resource (e.g., Wagar 1964, Lime and Stankey 1971). All three are important in determining capacity, but one component may be more significant than another depending on the type of recreational activity and area being considered.

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Carrying capacity then, is a management concept, a framework or way of thinking about how to plan and manage a particular recreation resource. It is not the basis for some magic formula that gives the manager the answer to the continuing question, "How much use is too much?"

Carrying capacity is a complex and troublesome concept that incorporates principles of the social as well as of the physical and biological sciences. It frustrates those attempting to conceptualize and apply it. There are numerous calls for more capacity research (Bureau of Outdoor Recreation 1975, Idaho Water Resources Research Institute et al. 1975). Moreover, public land managing agencies have received a mandate, through the Nationwide Outdoor Recreation Plan (Bureau of Outdoor Recreation 1973), to determine specific carrying capacities for their areas and to manage them accordingly. This commitment requires that:

> "Each Federal recreation land managing agency will determine the carrying capacity of its recreation lands, considering management objectives, ecological concerns, and user characteristics."
>
> "As a second step, each Federal recreation land managing agency will institute necessary controls and develop new ways of managing the movement of people to ensure that use does not exceed capacity."

Carrying capacity of recreation lands has been discussed in the literature since the 1930's, but attention intensified markedly in the 1960's and has continued into the 70's. Several recent attempts have been made to bring together and review literature relevant to the carrying capacity issue (Chubb and Ashton 1969, Ditton 1969). In 1971, Lime and Stankey published a state-of-the-knowledge paper. In 1973, we published an annotated bibliography with over 200 citations (Stankey and Lime 1973). Since that time, several other important papers have appeared that add depth to the carrying capacity concept and synthesize the growing body of literature on this subject (Conservation Foundation 1972a and 1972b, Lloyd and Fischer 1972, Fisher and Krutilla 1972, Frissell and Stankey 1972, Burden and Randerson 1972, Tivy 1972, Ashton and Chubb 1972, Hopkins et al. 1973, Alldredge 1973, Sudia and Simpson 1973, Lucas and Stankey 1974, Lime 1974, Ohmann 1974, Stankey 1974, Hammon et al. 1974a and 1974b, Wagar 1974, Ditton 1974, Conservation Foundation 1974, Verburg 1975, Pfister and Frenkel 1975).

In spite of the growing body of capacity literature, I contend that the basic conceptual framework for carrying capacity has changed little since the first definitive writing on the subject in the late 1950's and early 60's (Anderson 1959, LaPage 1963, Wagar 1964, Lucas 1964a). These and most of the others noted stress that carrying capacity considerations must recognize both the durability of the environment to sustain use and the ability of the site to produce a continuing flow of satisfactions and benefits to users.

Those interested in the philosophical and conceptual aspects of capacity, on biological and social research, and on techniques for managing for carrying capacity are urged to read these references. Verburg's paper(1975), especially, is the most recent review and an excellent synthesis of the previous work.

I will not review or summarize these previous papers. I will attempt, however, to briefly identify six basic principles that relate to carrying capacity and that seem relevant to outdoor recreation management in the South and elswhere.

Carrying capacity can be defined only in light of management objectives for the area in question.

Although the character of the resource can indicate the durability of a site under sustained use, almost any site could be "hardened" to accommodate the type of recreational opportunity called for by management. Management objectives should define, as specifically as possible, the kind of recreational opportunity or opportunities that the area is to provide.

Perhaps two types of management objectives can be differentiated: (1) broad objectives influenced or controlled by enabling legislation and general administrative policy; and (2) move explicit objectives that delineate the desired environmental setting to be sustained and user experience(s) the area is to produce.

Broad, general objectives typically: (1) could identify the kind(s) of activities that might be provided (e.g., camping, picnicking, fishing, sightseeing, and hunting); (2) whether consideration would be given to the protection of natural features; and (3) whether the area should be developed to serve as many people as possible or should be limited to one or more specific kinds of users, such as campers or hikers.

Explicit objectives typically are more difficult to define because they must identify what kind of experiences are to be provided, and how and where these experiences will be managed and sustained. The manager must be concerned with such issues as the following:

1. General use intensity or level of solitude desired,
2. Type(s) of use desired--automobiles, off-road recreation vehicles (ORRV's), horses, overnight and/or day-use, large groups,
3. Level of development and accessibility of recreation facilities desired--from simple to elaborate and remote to easily accessible that denote a range in the character, number, and location of facilities, and,
4. General degree of naturalness desired (on a continuum in which wear and tear to the resource is limited so it will recover naturally over time to an opposite situation in which the site is intensively managed and "hardened" in order to accommodate intensive use).

These more explicit objectives may also be influenced by administrative and policy constraints. Furthermore, limited funds, personnel availability, and technical limitations can inhibit certain objectives. Studies of user attitudes and preferences and research to determine environmental impacts of use also can help establish objectives.

Obtaining attitudes and preferences of recreation users and non-users can help administrators set objectives and may suggest needed changes in current policy.

Management cannot rely solely on public opinion as a basis for policy. Yet, there usually is more than one alternative for a giver management problem. Scientifically collected information provides a more accurate cross section of views than do public meetings or occasional letters and personal visits from highly motivated citizens. Such information provides inputs from publics not otherwise available.

Soliciting public opinion, however, does allow the manager to review the mix of attitudes that exists regarding a specific issue. Frequently, users and potential users disagree as to what they want--a quality experience to one person may be altogether unacceptable to someone else. Furthermore, and perhaps more importantly, user preferences may be quite different from manager preferences and from what managers believe the public wants (Stone and Taves 1958, Lucas 1964b, and 1970, Hendee and Harris 1970, Clark *et al*. 1971, Peterson 1974).

Gathering data on public attitudes can be especially useful in identifying the range and mix of public desires for a given recreation site or geographic region. Such information can help managers define *specific* conditions or actions necessary to achieve management objectives. For example, an agency might decide to provide basic camping facilities (accessible by automobile) in relatively remote locations. Studies of attitudes could provide indices of how visitors might respond to different-size campgrounds; the type of setting individual camp units are located in; spacing between units; the kind and spacing of toilets, water facilities, and other facilities (trails, playground equipment, etc.); the design of access roads; and, various information and interpretation materials.

Public attitudes can be categorized in an infinite number of ways. Groups might be differentiated by their: (1) perception of a site as a local, State, regional, or national resource; (2) motives for visiting the area; (3) previous outdoor recreation experiences; and (4) knowledge of alternative activities and areas. Wilderness users, for instance, have been categorized on the basis of how "wilderness oriented" their attitudes were (Hendee and Stankey 1973). Other research has identified differing attitudes for distinct use-seasons (Shafer 1969) and for different locations within a given recreation area (Beardsley 1967, Lucas 1964a, Lime 1971).

The results of such attitude surveys are not a substitute for management experience and good judgement. Nor do such studies make decisions easier for managers. On the contrary, results may increase the number of alternatives that must be considered. It also is important to know who may oppose various management actions. Once management decisions are made, especially on controversial issues, it may be as important to take appropriate steps to explain to these users why their preferences cannot be met as it was to learn about the mix of opinions in the first place (Lime 1972).

A full range of recreation opportunities within a region to satisfy the diversity of recreation tastes is desirable.

In setting management objectives and standards for an area such as Southern Appalachia, it seems imperative that managers think of developing a balanced system or spectrum of recreation opportunities. These should include not only a variety of regional recreation activities (hiking, swimming, hunting, boating, etc.) but also a range of different kinds of opportunities for a given activity such as auto-access camping (Lime 1974). No one manager or agency need feel obligated to meet the demands of all recreation users. Each public agency, for example, could aim at providing one or more specific types of recreation opportunities and refer those wanting something different to a more appropriate area.

Obviously, regionwide collaboration among private and public managers is mandatory if a full and appropriate mix of opportunities is to be provided. There does seem to be some dialogue among those managing developed campgrounds (Angus et al. 1971, Lime 1974). I have reviewed some long- and short-term management plans, which indicates that between them it is possible to provide the public with a full range of campgrounds from the most simple to the most elaborate. Some federal and State agencies now indicate they plan to take a major role in providing low-density, simple campground development and are encouraging the private sector to take the lead in providing intensively developed facilities. Although my review indicates that regionwide planning is possible, more coordination seems both desirable and necessary--for all types of outdoor recreation.

The character and amount of change permitted to occur to the resource resulting from recreation use must relate directly to management objectives.

The durability of an area's resources to withstand use is an important constraint on carrying capacity. But, knowing what changes occur under specific levels and kinds of use does not by itself tell the manager what is an acceptable amount of change. To define what change shall be permitted, the manager should relate resource change to specified management objectives.

There are many possible "standards of acceptable change" the manager could use. For example, in an elaborate, high-density-use camping area, the management objectives would allow the manager to employ a variety of techniques to offset resource impacts--such as paving, barriers, and planting hardy species. On the other hand, in a campground with a similar resource base but where the objective is to provide camping in a fairly natural setting, the amount of resource change permitted would be comparatively small. In this case the manager would probably rely on use restrictions rather than on techniques that would "harden" the site.

There are many techniques to manage an area for its carrying capacity; the techniques selected, however, should depend on the management objectives for the area.

A decade ago Alan Wagar (1964) developed a useful framework for discussing various ways to manage both natural resources and visitors for carrying capacity. He emphasized that the selection of a technique or combination of techniques to control the character and amount of use largely depends on the specific management objectives for the area. In doing this, managers should seek to: (1) reduce conflicts among competitive uses, (2) reduce the destructiveness of some users, (3) increase the durability of the physical resource, and (4) provide increased opportunities for visitor enjoyment. These goals can be achieved by the three overlapping types of control measures summarized in table 1 (Modified from Lime and Stankey 1971, Gilbert et al. 1972).

Table 1.--Some measures to control the character and intensity of recreational use to meet desired management objectives

Type of control	Method	Specific control techniques
Site Management (Emphasis on site design, landscaping, and engineering)	Harden site	Install durable surfaces (native, nonnative, synthetic) Irrigate Fertilize Revegetate Convert to more hardy species Thin ground cover and overstory
	Channel use	Erect barriers (rocks, logs, posts, fences, guardrails) Construct paths, roads, trails, walkways, bridges, etc. Landscape (vegetation patterns)
	Develop facilities	Provide access to underused and/or unused areas Provide sanitation facilities Provide overnight accommodations Provide concessionaire facilities Provide activity-oriented facilities (camping, picnicking, boating, docks, and other platforms, playground equipment, etc.) Provide interpretive facilities
Direct Regulation of Use (Emphasis on regulation of behavior; individual choice restricted; high degree of control)	Increase policy enforcement	Impose fines Increase surveillance of area
	Zone use	Zone incompatible uses spatially (Hiker only zones, prohibit motor use, etc.) Limit camping in some campsites to one night, or some other limit

Table 1. (continued)

	Restrict use intensity	Rotate use (open or close roads, access points, trails, campsites, etc.) Require reservations Assign campsites and/or travel routes to each camper group in backcountry Limit usage via access point Limit size of groups, number of horses, vehicles, etc. Limit camping to designated campsites only Limit length of stay in area (max./ min.)
	Restrict activities	Restrict building campfires Restrict fishing or hunting
Indirect Regulation of Use (Emphasis on influencing or modifying behavior; individual retains freedom to choose; control less complete, more variation in use possible)	Alter physical facilities	Improve (or not) access roads, trails Improve (or not) campsites and other concentrated use areas Improve (or not) fish or wildlife populations (stock, allow to die out, etc.)
	Inform users	Advertise specific attributes of the area Identify the range of recreation opportunities in surrounding area Educate users to basic concepts of ecology Advertise underused areas and general patterns of use
	Set eligibility requirements	Charge constant entrance fee Charge differential fees by trail, zone, season, etc. Require proof of ecological knowledge and recreational activity skills

Managers can employ many techniques in and around a recreation site to protect soil, vegetation, wildlife, and water. Such measures channel or restrict the movements of people thereby limiting the area they damage, provide surfaces that can withstand intensive use, and provide access and facilities to areas that are otherwise unused or very lightly used.

It is important to recognize that site management techniques have an immediate and significant affect on the character of the area and the kind of recreational opportunity offered. Hence, drastic or even seemingly subtle changes in the design and types of facilities used can alter the character of the site to the point that it may no longer be satisfactory to the current users. This transition has often been observed in small, informal campgrounds that have been closed or have evolved into large, modern, intensively-developed camping areas. The resulting process of "creeping campground development" forces out a sizable segment of those campers seeking solitude and contact with nature (Hendee and Campbell 1969, Clark et al. 1971, Lime 1974). In many areas these "displaced campers" can no longer find the type of camping areas they enjoy.

There also are many direct and indirect ways to control recreational use. By direct, I mean controls that directly regulate where and when visitors can use the area, how long they can stay, and what sorts of activities they can engage in. Some of these measures are very authoritarian and greatly restrict the user's freedom of choice.

Indirect controls, on the other hand, are more subtle and less obtrusive. They do not interfere directly with an individual's freedom of choice. The emphasis is on influencing the user to make choices that produce changes desired by the manager. In essence, the manager seeks to modify user behavior without the user being aware of this influence. For instance, reducing trail maintenance in certain areas might convince some hikers not to use those trails in favor of others that are better maintained. As another example, hikers seeking solitude could be informed specifically where use is lightest. In both examples, such actions could help redistribute use and might also help more people increase their enjoyment.

As a general strategy, I would urge that the indirect, more subtle types of controls be tried and evaluated first before the more authoritarian, heavy-handed kinds of actions are pressed into service. In particular, do not apply heavy-handed use restrictions because they appear cheapest or administratively convenient. When more regulatory types of measures are necessary, they should be applied as far in advance of the visitor's arrival at the site as possible (Lucas 1973, Magill 1974, Stankey et al. 1974). In established wilderness areas and in unroaded backcountry settings, controls should be applied before the visitor enters an area; and, the visitor should be free to roam within the area.

Ultimately, the recreation manager is still left with the difficult decision of deciding how much and what kinds of use are acceptable for a given area, and how and where such uses are to be managed and sustained.

For some decisions, the appropriate course of action is rather clear because there are few alternatives. In others, information necessary to make the decision may be meager or conflicting. Further, decisions may be influenced by administrative, legal, budgetary, and resource constraints.

Research can help a manager by finding out what people want from a recreation experience and what they think about alternative actions. It can also help by determining how the resource will be affected by various kinds and levels of use. In effect, however, such information only reduces the range of uncertainty associated with a given decision; it does not eliminate the uncertainty.

The point is that research, both social and biological, cannot be viewed as a panacea for management that will tell the recreation manager what to do. As I stressed earlier, there is no magic formula for capacity and there is no magic number that is the capacity for an area.

Without a marriage of managerial judgment and facts, the quest for quality recreation management appears destined for "rougher days ahead". Some warn that without adequate public participation in resource decision making "...resource managers will find themselves in the backwash of the environmental movement, serving as mere resource custodians with most decision making in other hands" (Hansen 1970).

LITERATURE CITED

Alldredge, Rendel B. 1973. Some capacity theory for parks and recreation areas. Trends, Oct., Nov., Dec.: 20-30.

Anderson, K. R. 1959. A user-resource recreation planning method. Natl. Advis. Counc. on Regional Recreation Planning, Hidden Valley, Loomis, Calif. 80 p.

Angus, J., C. Corssmit, and J. H. Foster. 1971. Criteria for public supply of outdoor recreation facilities. 37 p. Amherst Agric. Exp. Stn. Res. Bull. 592. Univ. Mass., Amherst.

Ashton, Peter G., and Michael Chubb. 1972. A preliminary study for evaluating the capacity of waters for recreational boating. Water Resour. Bull. 8(3): 571-577.

Beardsley, W. 1967. Cost implications of camper and campground characteristics in central Colorado. USDA For. Serv. Res. Note RM-86, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Burden, R. F., and P. F. Randerson. 1972. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. J. Applied Ecol. 9(2): 439-457.

Chubb, M., and P. Ashton. 1969. Park and recreation standards research: the creation of environmental quality controls for recreation. Rep. to the Natl. Recreation and Park Assoc. Tech. Rep. 5. Recreation Resource and Planning Unit, Mich. State Univ., East Lansing. 76 p.

Clark, R. N., J. C. Hendee, and F. L. Campbell. 1971. Values, behavior, and conflict in modern camping culture. J. Leisure Res. 3(3): 143-159.

Conservation Foundation. 1972a. National parks for the future. Washington, D.C.: Conserv. Found. 254 p.

Conservation Foundation. 1972b. National parks at the crossroads: drawing the line where protection ends and overuse begins. Conserv. Found. Letter, Sept. Washington, D. C. 12 p.

Conservation Foundation. 1974. Carrying capacity analysis is useful but limited. Conserv. Found. Letter, June. Washington, D.C. 8 p.

Ditton, R. B. 1969. The identification and critical analysis of selected literature dealing with the recreational aspects of water resources use, planning, and development. Res. Rep. 23. Water Resour. Center, Univ. Ill., Urbana. 293 p.

Ditton, R. B. 1974. Water resources management and carrying capacity applications. Proceedings of the Sixth Recreation Management Institute. Texas A&M Univ., Texas. p. 15.1-15.7.

Fisher, A. C., and J. V. Krutilla. 1972. Determination of optimal capacity of resource-based recreation facilities. p. 115-141. In Natural Environments. J. F. Krutilla, ed. Resour. for the Future, Inc., Washington, D.C. 352 p.

Frissell, Sidney S., Jr., and George H. Stankey. 1972. Wilderness environmental quality: search for social and ecological harmony. Soc. Am. For. Annu. Meet. Proc., Hot Springs, Ark. p. 170-183.

Gilbert, C. Gorman, George L. Peterson, and David W. Lime. 1972. Toward a model of travel behavior in the Boundary Waters Canoe Area. Environ. and Behavior 4(2): 131-157.

Hammon, Gordon, H. K. Cordell, L. W. Moncrief, M. R. Warren, R. A. Crysdale, and J. Graham. 1974a. Capacity of water-based recreation systems part I: the state of the art-literature review. Water Resour. Res. Inst. North Carolina State Univ., Raleigh, North Carolina. 49 p.

Hammon, Gordon, H. K. Cordell, L. W. Moncrief, M. R. Warren, R. A. Crysdale, and J. Graham. 1974b. Capacity of water-based recreation systems part II: a systems approach to capacity analysis. Water Resour. Res. Inst. North Carolina State Univ., Raleigh, North Carolina. 46 p.

Hansen, R. P. 1970. The resource manager and environmental quality: problems and opportunities. (Abstract) Soc. Am. For. Ann. Meet. Proc., Las Vegas, Nevada. p. 13-15.

Hendee, John C., and Frederick L. Campbell. 1969. Social aspects of outdoor recreation--the developed campground. Trends in Parks and Recreation 10: 13-16.

Hendee, John C., and Robert W. Harris. 1970. Foresters' perception of wilderness-user attitudes and preferences. J. For. 68: 759-762.

Hendee, John C., and George H. Stankey. 1973. Biocentricity in wilderness management. BioScience 23(9): 535-538.

Hopkins, F. S., Jr., G. H. Manning, and H. H. Webster. 1973. Planning for the future in outdoor recreation: an economic viewpoint. For. Chron. 49(2): 71-75.

Idaho Water Resources Research Institute, Oregon Water Resources Research Institute, and State of Washington Water Research Center. 1975. Regional problem analysis in the Pacific Northwest. Washington State Univ., Pullman, Wash. 122 p.

La Page, Wilbur. 1963. Some sociological aspects of forest recreation. J. For. 61: 32-36.

Lime, David W. 1971. Factors influencing campground use in the Superior National Forest of Minnesota. USDA For. Serv. Res. Pap. NC-60, 18 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Lime, David W. 1972. Behavioral research in outdoor recreation management: an example of how visitors select campgrounds. p. 198-206. In Environment and the social sciences: perspectives and applications, ed. by J. F. Wohlwill and D. H. Carson. 300 p., illus. Wash., D. C.: Am. Psychol. Assoc.

Lime, David W. 1974. Locating and designing campgrounds to provide a full range of camping opportunities. In Outdoor recreation research: applying the results. Papers from a workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. Gen. Tech. Rep. NC-9. p. 56-66. North Cent. For. Exp. Stn., St. Paul, Minn.

Lime, David W., and George H. Stankey. 1971. Carrying capacity: maintaining outdoor recreation quality. p. 174-184. In For. recreation symp. proc., N.Y. Coll. For., Syracuse, Oct. 12-14, 1971, 211 p. Northeast. For. Exp. Stn., Upper Darby, Pa.

Lloyd, R. D., and V. L. Fischer. 1972. Dispersed versus concentrated recreation as forest policy. Seventh World For. Congr. Proc., Buenos Aires, Argentina. 196(E): 18 p.

Lucas, Robert C. 1964a. The recreational capacity of the Quetico-Superior Area. USDA For. Serv. Res. Pap. LS-15, 34 p., illus. Lake States For. Exp. Stn., St. Paul, Minn.

Lucas, Robert C. 1964b. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Nat. Resour. J. 3(1): 394-411, illus.

Lucas, Robert C. 1970. User evaluation of campgrounds on two Michigan national forests. USDA For. Serv. Res. Pap. NC-44, 15 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Lucas, Robert C. 1973. Wilderness: a management framework. J. Soil Water Conserv. 28(4): 150-154.

Lucas, Robert C., and George H. Stankey. 1974. Social carrying capacity for backcountry recreation. In Outdoor recreation research: applying the results. Papers from a workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. Gen. Tech. Rep. NC-9. p. 14-23. North Cent. For. Exp. Stn., St. Paul, Minn.

Magill, Arthur W. 1974. Dispersal of recreationists on wildlands. In Outdoor recreation research: applying the results. Papers from a workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. Gen. Tech. Rep. NC-9. p. 101-106. North Cent. For. Exp. Stn., St. Paul, Minn.

Ohmann, Lewis F. 1974. Ecological carrying capacity. In Outdoor recreation research: applying the results. Papers from a workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. Gen. Tech. Rep. NC-9. p. 24-28. North Cent. For. Exp. Stn., St. Paul, Minn.

Peterson, George L. 1974. A comparison of the sentiments and perceptions of wilderness managers and canoeists in the Boundary Waters Canoe Area. J. Leisure Res. 6(summer): 194-206.

Pfister, Robert E., and Robert E. Frenkel. 1975. The concept of carrying capacity: its application for management of Oregon's Scenic Waterway System. Dept. of Geography, Oregon State Univ., Corvallis. 50 p.

Shafer, Elwood L., Jr. 1969. The average camper who doesn't exist. USDA For. Serv. Res. Pap. NE-142, 27 p., illus. Northeast. For. Exp. Stn., Upper Darby, Pa.

Stankey, George H. 1974. Criteria for the determination of recreational carrying capacity in the Colorado River basin. p. 83-101. In Environ. Manage. in the Colorado River Basin. Utah State Univ. Press, Logan, Utah.

Stankey, George H., and David W. Lime. 1973. Recreational carrying capacity: an annotated bibliography, USDA For. Serv. Gen. Tech. Rep. INT-3, 45 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Stankey, George H., Robert C. Lucas, and David W. Lime. 1974. Patterns of wilderness use as related to congestion and solitude. Assoc. Am. Geographers Annu. Meet. Proc., Seattle, Wash. 18 p. (mimeo)

Stone, Gregory P., and Marvin J. Taves. 1958. Camping in the wilderness. p. 290-305. In Mass leisure, ed. by Eric Larrabee and Rolf Meyersohn. 429 p. Glencoe, Ill.: The Free Press.

Sudia, T. W., and J. M. Simpson. 1973. Recreation carrying capacity of the National Parks. Guideline 3(3): 25-40.

Tivy, Joy. 1972. The concept and determination of carrying capacity of recreational land in the U.S.A. CCS Occas. Pap. 3, Countryside Commission for Scotland, Butteby, Redgorton, Perth. 58 p.

USDI, Bureau of Outdoor Recreation. 1973. Outdoor recreation--a legacy for America. USDI. 89 p.

USDI, Bureau of Outdoor Recreation. 1975. In Outdoor recreation research needs workshop Proc. Harper's Ferry, West Virginia. 110 p.

Verburg, K. 1975. The carrying capacity of recreational lands: a review. Occas. Pap. 1, Planning Div., Prairie Region Parks, Winnipeg, Manitoba, Canada. 70 p.

Wagar, J. Alan. 1964. The carrying capacity of wildlands for recreation. For. Sci. Monogr. 7, 23 p.

Wagar, J. Alan. 1974. Recreational carrying capacity reconsidered. J. For. 72(5): 274-278.

A CRITIQUE OF THE PAPER ENTITLED "SOME PRINCIPLES OF RECREATIONAL CARRYING CAPACITY"

Leo F. Marnell[1/]

The concept of recreational carrying capacity has gained wide acceptance during the past decade among practitioners of outdoor recreation management. But the transformation of theory into on-site planning and management is an awesome task, one that appears to be progressing with some difficulty. Perhaps recreation management as a profession is on the threshold of an era where necessity will dictate the required solutions.

The author is cautious in his treatment of the subject. This, however, is understandable in view of the turmoil which accompanied the early evolution of the concept. Acceptance of recreational carrying capacity as a workable approach was initially set back by misguided enthusiam. Many proponents failed to comprehend the difficulty of interfacing a conceptual model with the realities of applied management. The procedure advocated by Dr. Lime provides planners with a notion of the appropriate end product, but it remains ultimately the manager's task to find the most acceptable way to accomplish this. The author's approach to carrying capacity determination does not promise a clear path to easy solutions. As noted in the paper, decisions should be made better, but they will not necessarily be made easier. Perhaps, the greatest value of the concept is that it provides a framework for identifying the most important considerations in management decision-making.

Recreational carrying capacity is a multi-dimensional concept. The goal of management is to maintain the quality of the resource and sustain user enjoyment at some predetermined level. The word "predetermined" is significant and forms the basis for a lengthy discussion of management objectives. A "hierarchy of objectives" is examined by the author with consideration directed first to the role of enabling legislation, broad general policies, etc. Although these mandates identify some of the basic constraints, the manager eventually arrives at that level of decision-making which requires a choice between alternatives, and often there are many. Several approaches are suggested as aids (i.e., research, public opinion surveys, etc.), but it is also recognized that a manager will often be required to make judgments not totally acceptable to his clientele. One caveat not mentioned, though it is implied under the term "administrative constraints", is the matter of political influences on management decision-making. This is not a point worth belaboring, but the record shows that it is a factor which public land managers must reckon with. Not even the most scientifically based approach to carrying capacity determination will survive intact if circumstances bring adverse political pressures to bear.

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Some penetrating questions are posed by the author's suggestion that recreation planners (federal, state, private, etc.) in a given geographic region collaborate to provide a "balance system or spectrum of recreational opportunities." Few would challenge the desirability of such an effort, but the prospects for success are questionable. Of paramount importance, at least in the case of public recreation resources, is the necessity of instilling this kind of thinking in our legislators. A balanced complement of recreation resources within a region will require vision and careful planning at this level. Interagency cooperation in such a venture is not an insurmountable barrier as long as goals and objectives remain within the scope of the various agencies' governing policies. Perhaps to stimulate the involvemnnt of state agencies and private enterprise in such a venture, the federal government should consider grants or other subsidies contigent upon cooperating parties filling certain voids in the "spectrum". The benefits of what could be gained through this approach might make the effort worth pursuing.

Included in the paper is a table describing strategies for regulating use within established limits. Although not detailed, the list outlines adequately the basic alternatives for manipulating both people and resources to achieve prescribed objectives.

Not a great deal has been done in the way of on-site implementation of current theories in recreational carrying capacity, but several efforts have gone forth with modest success. With the current interest in recreation research, positive results may soon be realized on a broader scale. The central theme of the paper might have been strengthened by the inclusion of a few "case histories" describing the results of pioneer efforts in establishing carrying capacity. Overall, the author has done an admirable job of probing the complexities of a provocative and widely talked about subject.

HUNTERS AND HUNTING: MANAGEMENT IMPLICATIONS OF RESEARCH

John C. Hendee and Dale R. Potter[1]

Abstract.--Data are summarized from 33 studies pertaining to hunting participation--hunter characteristics including age, education, occupation, income, residence; hunter motives; membership in sportsmen organizations and reading of sporting magazines; antihunting sentiment; and nonconsumptive wildlife use. These data are interpreted for implication about the future importance and nature of hunting and wildlife management. The authors see the continued importance of hunting but perhaps at reduced levels. The provision for and integration of opportunities for both hunting and wildlife appreciation are an important resource management challenge.

Keywords: Hunting, hunter characteristics, hunter motives, antihunting, nonconsumptive wildlife use, wildlife management.

INTRODUCTION

Hunting has been a popular American activity ever since nomadic groups crossed the Bering Straits in pursuit of game. These first native Americans depended on their hunting success for survival. But even then, hunting was more than a source of food. The legends and folklore of early American cultures abound with references to the festivity, glory, and satisfactions of the hunt. Even then hunting was pleasurable as well as necessary.

Likewise, the folklore describing white colonization of the American frontier is replete with reference to hunting as a recreational activity, a source of food for the spirit as well as the body.

Today, the pleasures associated with hunting still have an important place among our cultural traditions, although 20th century development has severely reduced game habitat and free opportunities to hunt. As industrialized society grew in the United States, millions of acres of game habitat were wiped out by urban sprawl, population growth, commercial development, the advent of agri-business, reclamation of marshland and desert, and clean cropping of arable land. The loss of rural American lifestyle has also been important in its impact on the prevalence of hunting. Today, most Americans are second or third generation urbanites who have not spent their youth close to the "split rail" values described by Leopold (1949). They are removed from the influence of rural traditions and values which foster hunting as a recreational outlet and a supplemental source of food.

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Fortunately for hunters and game alike, the urbanization and industrialization of America were accompanied by the development of several natural resource management professions--forestry, wildlife and range management--and by many State, federal, and private wildlife organizations. These professions and organizations are devoted to applying modern concepts and management techniques to make our scarce natural resources go farther in meeting increasing and competing demands. Some game species such as deer, elk, and turkey have increased in response to management.

Within the modern resource management context, hunting is incorporated in a larger land use planning equation. In this planning process, the many demands for use of natural resources are evaluated by managers with the help of the public. Many managers and hunters are concerned about the weight given to hunting in the overall planning process. Some think that interest and participation in hunting is decreasing in the United States in favor of nonconsumptive uses of wildlife. Conflict is already evident between hunters and segments of the public opposed to hunting on grounds that it is a barbaric and intolerable activity in modern society. For their part, hunters quote managers' claims that some game can be harvested each year to maintain healthy populations. They also point to the crowded ranks of nimrods as evidence of the popularity of their sport.

Guiding the future development of hunting and game management will not be easy. This planning must take advantage of the latest research-based information. In this paper, we summarize data from more than 33 studies of hunters and discuss their implications for important game management issues and concerns.[2/] In particular, we will try to use these data to forecast future participation in hunting as a consideration in resource management and to lay a groundwork for the management challenges to come.

HOW POPULAR IS HUNTING?

The many competing demands for land use challenge managers to evaluate the impacts of all potential uses. One measure of a recreation activity's impact and popularity is the number of persons that participate.

Nationally, hunting is a popular sport. About 16.4 million persons hunted in 1974 or nearly 8 percent of the U.S. population over 12 years old. Since 95 percent of hunters are males, this means that almost 15 percent of U.S. men are hunters. For comparative purposes, consider that only 4 percent of the U.S. population snow ski, 9 percent hike, and 14 percent camp (U.S. Bureau of Outdoor Recreation 1971).

[2/] See appendix 1 for a list of studies summarized in this paper and background information on them. Other reviews of studies appear in Peterson (1969) and Schole (1973). Additional literature on related human behavior aspects of wildlife are annotated in Potter et al. (1973a) and the state of knowledge and need for specific research assessed in Hendee and Potter (1971).

Trends in hunting participation are complex. The 16.4 million licensed hunters in 1974 (U.S. Department of the Interior 1975) reflect a 16-percent increase in number since 1961 (fig. 1A).

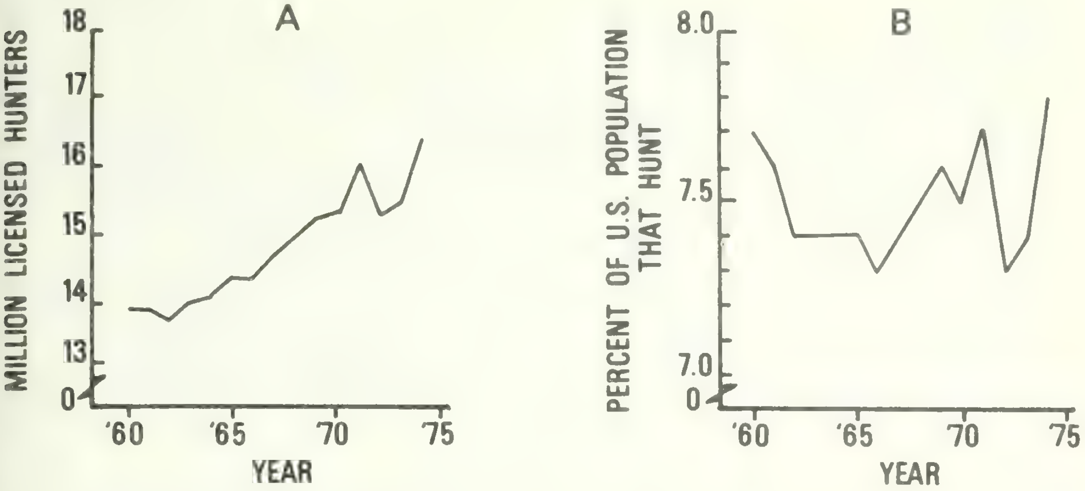

Figure 1.--Trends in the number of licensed hunters in the United States and percent of licensed hunters in the population. (Only licensed hunters are shown; a 1960 national survey showed that one hunter in five is unlicensed (U.S. Department of the Interior 1961).) Source: Compiled from U.S. Department of the Interior Fish and Wildlife Service records.

This trend suggests continued growth in the absolute numbers of hunters, but it does not show whether hunting is holding its own in relation to general population growth. Figure 1B shows licensed hunters as a percentage of U.S. population and indicates that the proportion of hunters in the population fluctuates from year to year. But the overall trend is neither up nor down and has remained between 7 and 8 percent for the last 15 years. In other words, these two graphs show that, nationally, the absolute number of hunters continues to increase, but hunting participation has held its own during the last 15 years in the proportion of the American public that hunts.[3/]

Figure 2 shows that there is considerable regional variation in hunting participation among the nine U.S. census regions as reflected by number of licensed hunters and percent of the population that hunted in 1970 in each region. Participation ranged from a high of almost 17 percent in the Mountain States, to a low of 5 percent in New England, Middle Atlantic, and Pacific regions. This regional variation appears to be related to a number of factors such as population density, urbanization, land ownership, hunting opportunity, game populations, and regional subcultures.

Clearly, hunters are a minority group but so are other prominent outdoor recreation groups--such as skiers, hikers, and campers. Urban sprawl and

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[3/] For an excellent discussion of trends in hunting license totals dating back to 1937, see Poole (1964).

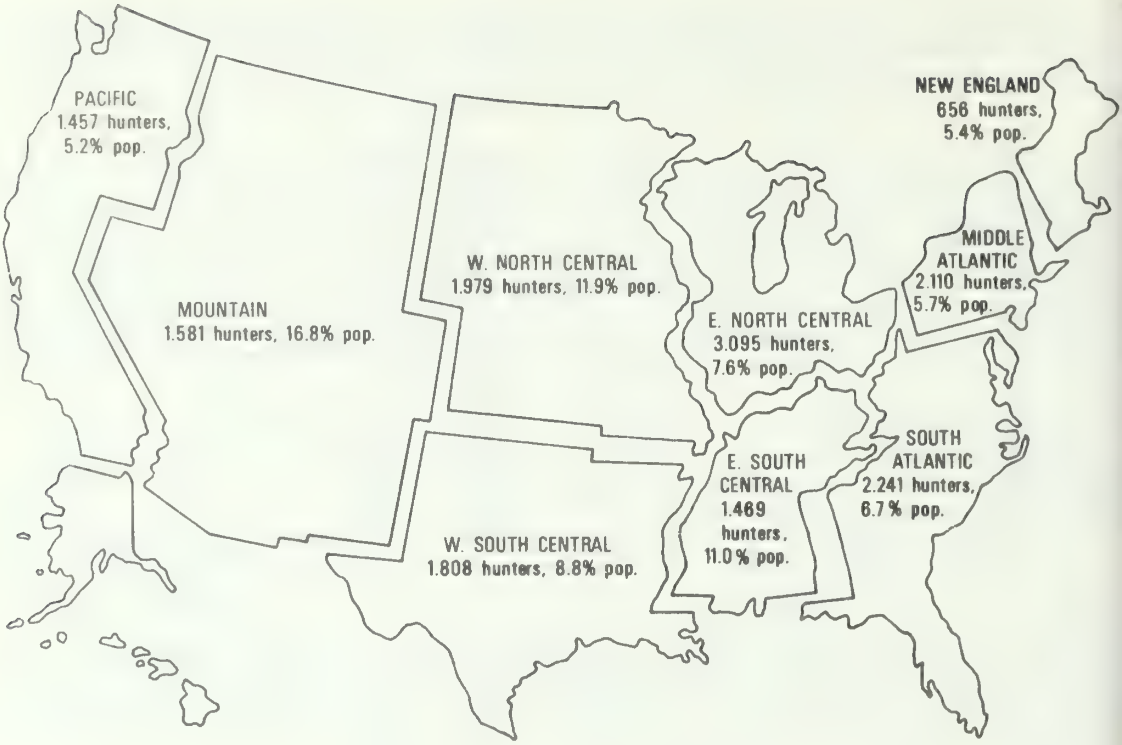

Figure 2.--Number of hunters (millions) and percent of population that hunted during 1970 by regions. Source: U.S. Department of the Interior 1972.

development continue to reduce game habitat and hunting opportunities. But the demand for hunting seems likely to continue.

What do these trends mean to wildlife managers? First, the increasing numbers of hunters will cause additional hunter crowding and make it more difficult for managers to provide quality experiences. This is particularly true considering that the amount of land available to support game and hunting is declining, with few exceptions. Second, the relatively constant proportion of the population that hunts shows no signs of predicted downturn in hunting participation. The Southeast River Basins Commission presents figures showing that the per capita demand for hunting was not expected to be sustained beyond 1975; and by the year 2000, the percent of user days of hunting will decline (U.S. Study Commission, Southeast River Basins 1963). Another assessment indicates that by 1985 the proportion of the population that hunts will not only decline but the absolute numbers likewise will be reduced (Cicchetti 1969).

Such predictions are viewed with much alarm in some quarters, even though not yet substantiated. Paradoxically, some persons fear the demise of hunting if the historical yearly increase in hunters is not sustained. But it is incongruous to believe that wildlife management can increase or even maintain the supply of game and its supporting habitat in the face of ever increasing demand. These are limits to growth! Another view is that a leveling off--perhaps even a little decline--in hunting participation will be a blessing in disguise to bring demand in balance with a constant or slowly decreasing supply. The provision of quality hunting and maintenance of the sport as a rewarding and popular American activity depend on such a balance.

WHO ARE THE HUNTERS?

Surveys of the demographic characteristics of hunters--age, education, occupation, income, and residence--provide information important to resource managers. Like market surveys, these studies of game management clientele have direct implications for communicating, anticipating preferences and desires, and identifying the beneficiaries of a sport that draws on public resources.

The following demographic data are synthesized from numerous studies. In a strict sense, these studies cannot be added together or averaged because of differences in sample populations, research methods used, type of data collected, and categories used in reporting. However, we are attempting to present a "state of knowledge" composite based on existing information. The following figures were constructed and estimated around data described in detail in appendices 2 through 6.

To give perspective, we often compare hunter characteristics with those of the general population and wilderness recreationists. Wilderness use was selected for comparison because this activity, like hunting, is a strenuous outdoor activity. The characteristics of wilderness users have been well established by research. Following the presentation of data about the demography of hunters, the implications of this composite are considered.

Age

The age distribution for hunters is somewhat skewed toward older age classes compared with the general population (fig. 3 and appendix 2). Unlike the general population, which includes more older and younger persons, hunters are predominantly middle-aged adults. More than 40 percent are between 26 and 45 years old, although hunters are found in all age categories except the very young.

It is important to note that only 14 percent of all hunters are under 20 years old because studies indicate that most hunters--some 90 percent in one study (Klessig and Hale 1972)--are initiated into hunting before they reach 20 years of age. Population trends may indicate a decreased number of young people initiated into hunting in the future, because census data reveal a downward trend in the numbers in younger age groups in the U.S. population. The age group from 12 to 17 years dropped nearly 7 percent over a recent 5-year period and nearly 15 percent for the 18- to 24-age group (Slater 1972).

Education

Eighteen studies from nearly as many States show that hunters are fairly typical, averaging only slightly more education than the general population. A slightly greater proportion of hunters has gone beyond a high school education than the general public (fig. 4 and appendix 3). In this respect, hunters are more "average" than wilderness users, who tend to have much more education than the general population.

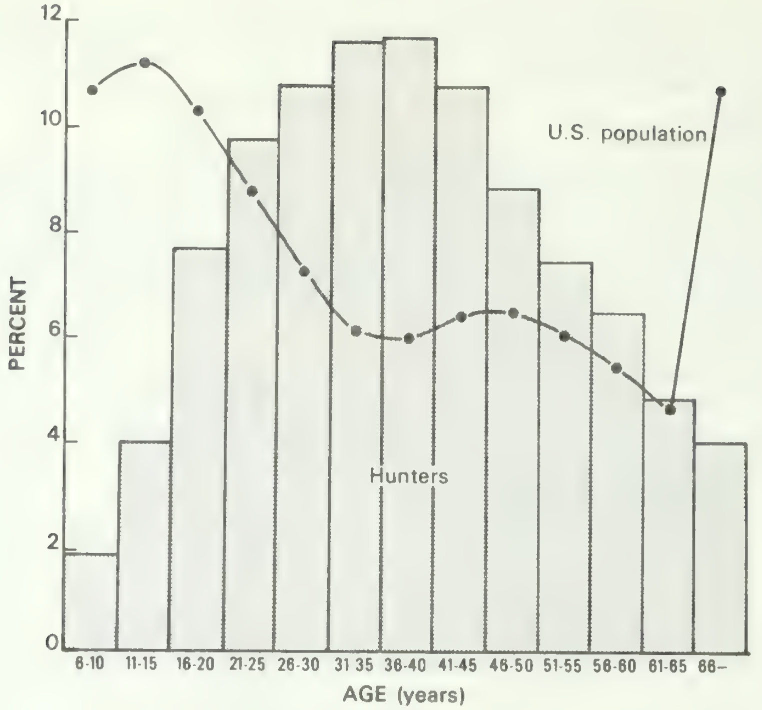

Figure 3.--Age distribution of U.S. hunters compared with U.S. population (see appendix 2 for specific hunter data from 20 studies).

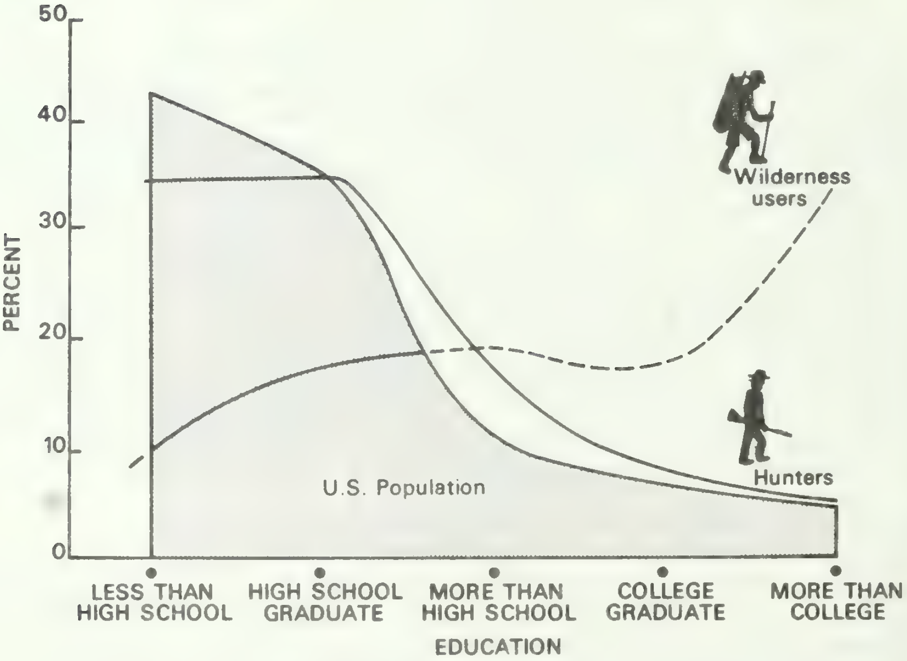

Figure 4.--Educational attainment of U.S. hunters, compiled from 18 studies, compared with the U.S. population and wilderness users (see appendix 3 for specific hunter data). Wilderness data source: Hendee (1967).

Occupation

The occupational distribution of hunters varies according to the region and type of hunting studied but closely resembles the general population (appendix 4). A synthesis of numerous studies shows hunters to be about 20-percent white collar and 40-percent blue collar with the rest distributed among sales, service, agriculture, and other categories.

Hunters are sometimes characterized as a blue collar group; but even though there may be more in this occupational category than in others, the distribution approximates the general population. Wilderness users, on the other hand, are drawn heavily from the ranks of professional and managerial occupations (Hendee et al. 1968, Vaux 1975).

Income

The income distribution of hunters approximates that of the general population, and hunters appear in all income brackets (fig. 5 and appendix 5).

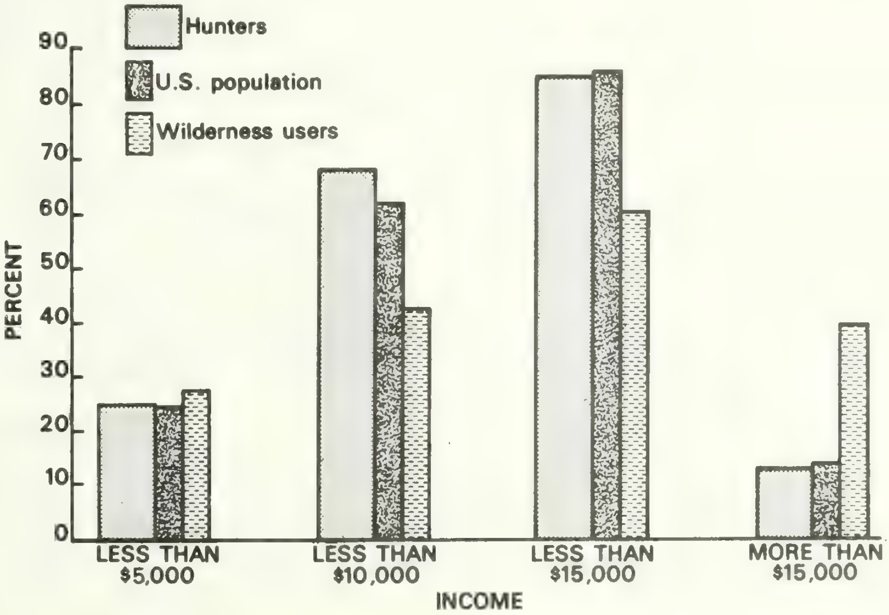

Figure 5.--Income of hunters compared with U.S. population and wilderness users (see appendix 5 for specific hunter data from 18 studies). Wilderness data source: Hendee (1967).

About 25 percent earn less than $5,000 annually, and 15 percent earn more than $15,000. Thus, hunting does not over-represent either the rich or the poor, although collectively these two groups account for nearly 40 percent of all hunters. Wilderness users, on the other hand, include a greater proportion (40 percent) from higher income groups. This is undoubtedly related to their higher educational and occupational classifications. Again, the main point is that hunters closely approximate the general population.

Residence

Whereas hunting is often described as an activity of rural residents (Outdoor Recreation Resources Review Commission 1960), data from 16 studies indicate the contrary (appendix 6). Only one study in the Southeast found more than half of the hunters had rural residences. On the other hand, six out of seven studies indicate that a majority of hunters spent part of their childhoods in rural areas.

IMPLICATIONS OF HUNTER CHARACTERISTICS

A composite view of the demographic characteristics of hunters indicates that hunters are primarily young to middle-aged adults, just slightly better educated than the general population, of average occupational classification and income, and primarily urban residents with rural backgrounds. Compared with both hunters and the general population, wilderness users have higher education, occupational classification, and income.

Some of the implications of these demographic data are as follows. The benefits of hunting, whatever they may be, are being distributed to a rather typical group of Americans. The fact that they hunt and are more likely to have a rural upbringing are about the only characteristics found to distinguish hunters from the rest of the U.S. population.

Most Americans reside in urban areas and so do hunters. But hunters tend to have been raised in rural areas. The decline in rural influences in America may signal a decline in activities associated with rural lifestyles and memories such as hunting.

A potential decline in hunting participation may also be implicit in the demographic breakdowns. Most hunters are introduced to the sport before they are 20 years old, but recent trends show recruitment into hunting is declining in the young age classes.

HOW ORGANIZED ARE HUNTERS?

The organization of hunters, including the proportion of hunters belonging to sportsmen's organizations and those who subscribe to sportsmen's magazines, reflects potential political strength and indicates the development of communication channels among hunters.

Ten studies (table 1) indicate that from 18 to 47 percent of hunters belong to sportsmen's organizations, but the average is about 25 percent. This makes hunters one of the most highly organized outdoor recreation groups, comparable to wilderness users, about 20 percent of whom belong to conservation groups or outdoor clubs (Hendee et al. 1969). Although many of the hunting and sportsmen's organizations are local, the powerful National Rifle Association, organized in 1871, claims over a million members. Additionally, one staunch antihunting personality points out that the following organizations are prohunting or at least do not oppose it: American Humane Society, Sierra Club, National Audubon Society, National Geographic Society, American Forestry Association, Wildlife Society, Izaak Walton League of Americans, National Wildlife Federation, and Boone and Crocket Club (Amory 1974). The point is that hunting has considerable backing.

Table 1.--Hunter membership in sportsmen's organizations

Location of study	Year studied	Population studied	Citation	Members
				Percent
Kansas	1967	Fish and Game Magazine readers	Zimmerman (1968)	46.9[a]
Maine	1965	Hunters and fishermen	Lobdell (1967)	18.5
Northeast	1965	Hunters	Bevins et al. (1968)	25.0
Ohio	1959	Hunters	Peterle (1961)	24.0
Pennsylvania	1965	Hunters	Sofranko and Nolan (1970)	27.3
Southeast	1971	Small game hunters[b]	Horvath (1974)	17.7
Texas	1973	Hunters	Berger (1974)	18.8
Washington	1971	Hunters	Potter et al. (1973b)	18.0
Wisconsin	1970	Waterfowl hunters	Eisele (1970)	36.0
Wisconsin	1968	Hunters	Klessig and Hale (1972)	22.0

[a] This figure is probably atypical because sportsmen's magazine readers are more likely to belong to sportsmen's organizations.

[b] Other hunter types include big-game hunters, 20.9 percent; waterfowl hunters, 28.5 percent.

A few studies have looked at the proportion of hunters who read sportsmen's magazines. Surprisingly, about 60-80 percent regularly read one or more sportsmen's magazines (Zimmerman 1968, Potter et al. 1973b). Outdoor Life, Field and Stream, and Sports Afield were by far the most widely read sportsmen's magazines, followed by local and regional sportsmen's newspapers and magazines.

Thus, hunters are relatively well organized and have a well-developed communication network, both prerequisites to political strength. Hunting values and information about issues of concern are continually disseminated to hunters. This organization and communication network will help foster the continuation of hunting and will protect it from adversaries.

WHY DO PEOPLE HUNT?

Philosophizing about why people hunt has been popular for a century or more, but only recently have motives for hunting been a topic for research. It is worthy of rigorous research because it can tell managers what kind of experiences hunters are seeking. From one perspective, the real products of game management are hunting experiences and the satisfactions and benefits to which they lead (Hendee 1974). Managers need to know what kinds of experiences are desired so they can manage game, land, and hunting conditions to produce an optimum mix of favored experiences.

At least 16 studies report why people hunted or yield other information related to hunters' motives and preferences.[4] These studies, using different methods and conducted under varying conditions, have yielded consistent findings. Two important concepts emerge. First, there are several general pleasures or satisfactions that people get from hunting. Second, although harvesting game is an obvious goal of hunters, it is not reported as the only or primary satisfaction in hunting.

If we translate the many reasons (one study listed over 70) given for hunting in these studies into the conceptually similar pleasures or satisfactions they suggest, the following emerge: nature appreciation; companionship; shooting; using skills; vicarious enjoyment from anticipation, recall, hearing, and reading about hunts; harvesting game (success); displaying one's ability and success; using special equipment; physical exercise; recreational diversion; relaxation; escape from civilization; and esthetic enjoyment. Although the studies of hunters' motives and preferences use a variety of terminology, the satisfactions described above account for the most commonly reported attractions of hunting.

Harvesting game, or success, is an important satisfaction; but it is only one of many. A statewide study in Washington (Potter et al. 1973c) showed success ranked eighth--behind nature appreciation, escapism, companionship, and four other hunting satisfactions. Some minimum probability or level of success is important to hunters and is no doubt necessary to activate or enhance other hunting satisfactions, but most studies of motives for hunting indicate that other satisfactions are more important.

What these data indicate is that hunting is similar to other kinds of outdoor recreation in that it is a way of getting a variety of diverse satisfactions. With the amount of available game dwindling and success per hunter declining, hunting satisfactions other than success are likely to be even more important. Game and land managers must coordinate their efforts to provide hunters with quality experiences in a broad sense. The kinds of experiences available to hunters are strongly affected by management practices unrelated to game production--e.g., road access, camping opportunities, controls on congestion and crowding, communication efforts, and law enforcement.

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[4] Davis 1962, Kirkpatrick 1965, Davis 1967, Ashcroft 1967, Bevins et al. 1968, Garrett 1970, Klessig and Hale 1972, Doll and Phillips 1972, Haulsee et al. 1973, More 1973, Potter et al. 1973b, Potter et al. 1973c, Schole et al. 1973, Stankey et al. 1973, Kennedy 1974, Horvath 1974.

Since hunters seek a variety of experiences, managers can satisfy more hunters by providing a full spectrum of hunting opportunities. Then hunters can pick and choose the kinds of experiences they want rather than being forced into a homogeneous mold. Unfortunately, some activities in resource management operate against diversity. For example, increasing the number of roads in managed forests eliminates opportunity to stalk game away from civilized improvements and encourages only "road hunting". Likewise, the need to sell more and more hunting licenses to generate needed revenue tends to produce quantity rather than quality hunting.

SOME CURRENT ISSUES

Antihunting Sentiment

Hunters and game managers are concerned about the potential influence of antihunting sentiment on the acceptability of the sport. Part of the anxiety arises from not knowing the effect that antihunting commentary may have on broader public opinion and its subsequent impact on hunting as an activity managed primarily by public agencies.

How many people oppose hunting, and what are their reasons? The findings of five studies are illuminating. Two studies in New Jersey revealed that a large proportion (38 percent in 1972 and 43 percent in 1974) of the general population disapproved of deer hunting. Although those that approve still outnumber those that disapprove, the margin has declined from 16 to 6 percent in 2 years (Applegate 1973, Applegate 1975). Opposition to hunting in New Jersey was associated with urban residence and appears to be stronger than in some other regions. A study in 11 Southeastern States found only 5.5 percent of the population opposed to hunting (Horvath 1974).

Dale Shaw (1973) studied antihunting attitudes among students in five universities across the country on the premise that these young adults will occupy future positions of influence. He found that 75 percent of the students expressed some antihunting or antihunter sentiment, and 19 percent were totally against sport hunting. In another study, William Shaw (1974) found antihunting opposition grounded in negative attitudes about the behavior of hunters, sympathy for individual animals as victims, and concern about the disruption of nature's balance.

At least 25 organizations, all but 4 being national or international in scope, have been identified with an antihunting objective (Frodelius 1973). In 1973 these groups claimed a total membership of 314,000 persons. Frodelius determined that the antihunting opinions of these organizations rested on negative reactions toward killing of wildlife, methods of hunting, management methods, fear of wildlife extinction, and to hunters as a class of people.

The issue of antihunting sentiment provokes "heat" whenever it comes up among game managers or hunters, both of whom understandably feel their interests are threatened. Resource managers must recognize that the issue involves a conflict of values--a situation that may be better understood, but not resolved, by any objective assessment of the logic underlying divergent views. Antihunting groups reflect one value system resting on a variety of supporting reasons. Likewise, prohunting advocates hold just as strongly to their view based on many other reasons. Attacks on the reasons underlying these divergent perspectives will not necessarily change either the orientations or the values of those who hold them. But by knowing more about the basis for antihunting sentiment, managers and hunters can minimize their vulnerability to criticism.

What can game managers and hunters do to disarm the criticism of antihunters? Several things seem important. First, hunter information, training, and safety programs need renewed emphasis to reduce hunting accidents, promote sportsmanship, instill a conservation ethic, build respect for property owners, and bring the realization among all hunters that their behavior contributes to an image of hunting that may affect its acceptability to the public at large.

Second, more effective programs are needed to promote and extend wildlife related law enforcement including trespass and property protection regulations. Soliciting hunter cooperation in reporting game violations may be helpful in pursuing this goal under current shortages of agency money and manpower. Several States have initiated such programs.

Third, hunting literature, advertising, and movies should be encouraged to feature positive recreational and esthetic aspects of hunting. The killing of game animals and trophy hunting should not be emphasized since they are only two of the many aspects of the sport that attract hunters. Hunting should be featured as a source of varied, recreational satisfactions and healthy outdoor activity. That's what it really is.

Fourth, better definitions are needed of what is or is not acceptable sport hunting, and the responsibilities of sportsmen, game managers, and landowners in enforcing such a code.

Who should take the leadership role in promoting and implementing the above recommendations? The authors feel this is the proper role for State game agencies because they are at the fulcrum, balancing the concerns of sportsmen and landowners while being legally responsible for game populations. The president of the Wildlife Management Institute (Poole 1971) makes this same point very emphatically; "we cannot wait much longer in some areas. State agencies have got to face up to their responsibilities, even to the point of ramming it down the throats of sportsmen where the alternatives are clear." And we might add that the State agencies' very survival may depend on such forceful action if current critics of hunting are to be denied real world examples of situations and incidents that fuel antihunting sentiments.

The impact of antihunting sentiment on resource management will be negotiated, in large part, through political processes. There is some concern that endorsement of hunting is decreasing, especially among college students and urban residents. This may combine with other factors such as diminished hunting opportunity, rural lifestyles and values, and population trends to reduce future numbers of hunters. On the other hand, the political base of hunters in sportsmen's organizations and their network of communication through sportsmen's magazines still seem a powerful force for protecting the future of hunting.

Nonconsumptive Wildlife Use

Nonconsumptive or appreciative use of wildlife is becoming more prevalent according to a 1970 survey indicating the presence of 6.3 million birdwatchers and 4.5 million bird and wildlife photographers (U.S. Department of the Interior 1972). A study in 11 Southeastern States found that over half the households surveyed each averaged 146 days of birdwatching (Horvath 1974).

This use produces economic expenditures amounting to millions. The total direct expenditures for the enjoyment of nongame birds, for example, were estimated at $500 million in 1974. Expenditures for birdseed, binoculars, and camera equipment constituted 95 percent of this total (Payne and DeGraaf 1975).

Most wildlife managers enthusiastically applaud this widening horizon of their professional responsibility. But they are dismayed that so little is known about the kind and extent of appreciative use of wildlife species by a growing segment of the public. Some managers are apprehensive about growing demands to manage for wildlife appreciation while there is scarcely enough time and money for game management which pays the bills. This anxiety is well founded since 62 percent of all wildlife management money comes from hunting and fishing license sales, another 20 percent from tax on guns and ammunition and only 5 percent from general State tax revenues (Wildlife Management Institute 1973). Innovative approaches to finance nonconsumptive wildlife such as sale of wildlife stamps and personalized license plates either have failed or have fallen well short of management needs and expectations. Some equitable and long-term financing of nonconsumptive wildlife management is desperately needed. Nonhunting programs should not be carried out at the expense of hunting interests but in addition to them with separate and adequate funding. General tax revenues are one logical source, but these will require good supporting information about the extent of wildlife appreciation among the public, the benefits derived, and how management programs can optimize them.[5/] In the meantime, minimizing conflicts between the two uses is an obvious challenge to resource management. Skillful management can minimize conflicts between consumptive and nonconsumptive uses by separating them over time, space, and use of wildlife habitat and populations. The impact of growing nonconsumptive uses of wildlife on hunting will depend, in large part, on how well managers meet this challenge.

CONCLUSION

Future increase in sales of hunting licenses is indicated by the data. However, this may change as evidenced by a stabilized proportion of the population that hunts and in response to increasing antihunting sentiment, urbanization of American society, population changes, competition for wildlife, habitat and game populations, and conflicts in wildlife values. This is not to suggest that hunting will die out altogether. About 20 percent of all hunters belong to sportsmen's organizations, a political advantage; in even the heavily urbanized and populated regions of the country such as the Northeast,

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[5/] Recent research on nonconsumptive wildlife include: Gray 1975, U.S. Department of Agriculture 1975, Noges and Progulske 1974, Kellert 1974, Hansen and Simmons 1974, Schweitzer et al. 1973.

where hunting participation is lowest, stable trends in hunting participatio have prevailed for years (U.S. Department of the Interior 1956, 1961, 1967, 1972). Stabilized or even slight decline in participation may help balance supply of hunting opportunities and demands leading to better quality huntin The strong emergence of nonconsumptive uses suggests that total wildlife management--for hunting and nonconsumptive appreciation--will be an increasingly important consideration for resource management.

LITERATURE CITED

Amory, Cleveland.
1974. Man kind? Our incredible war on wildlife. 372 p. New York: Harp and Row.

Applegate, James E.
1973. Some factors associated with attitudes toward deer hunting in New Jersey residents. Proc. 38th North Am. Wildl. Nat. Resour. Conf. Reprinted in Human dimensions in wildlife programs, ed. by John C. Hende and Clay Schoenfeld, p. 111-117. Wildl. Manage. Inst.

Applegate, James E.
1975. Attitudes towards deer hunting in New Jersey: a second look. Wildl Soc. Bull. 3(1):3-6.

Ashcroft, William H.
1967. The socio-economics of recreational use of the Cache elk herd. M.S. thesis, 77 p. Utah State Univ.

Berger, Michael E.
1974. Texas hunters: characteristics, opinions and facility preferences. Ph. D. diss., 131 p. Texas A and M.

Bevins, Malcolm I., Robert S. Bond, Thomas J. Corcoran, Kenneth D. McIntosh, and Richard J. McNeil
1968. Characteristics of hunters and fishermen in six Northeastern States. Northeast Reg. Res. Publ., Agric. Exp. Stn., Univ. Vt., Burlington, Vt. Bull. 656.

Cicchetti, C. J., J. J. Seneca, and P. Davidson
1969. The demand and supply of outdoor recreation, an economic analysis. Rutgers Univ. Bur. Res., New Brunswick. 301 p.

David, William C.
1962. Values of hunting and fishing in Arizona, 1960. Bur. Bus. and Publ. Res., Univ. Ariz. Spec. Stud. No. 21. 61 p.

Davis, William C.
1967. Values of hunting and fishing in Arizona in 1965. Coll. Bus. and Publ. Adm., Univ. Ariz. 91 p.

Doll, G. Fred, and Clynn Phillips
1972. Wyoming's hunting and fishing resources, 1970. Div. Bus. Econ. Res. Univ. Wyo. 116 p.

Eisele, Timothy T.
1970. Wisconsin waterfowl hunter attitudes on regulations and management policies. M.S. thesis, 123 p. Univ. Wis.

Folkman, William S.
1963. Levels and sources of forest fire prevention knowledge of California hunters. USDA For. Serv. Res. Pap. PSW-11. 22 p.

Frodelius, Ronald B.
1973. Determination of anti-hunt organizations by content analysis of their literature. M.S. thesis, SUNY, Syracuse.

Garrett, James R.
1970. Characteristics of Nevada hunters. Univ. Nev., Agric. Exp. Stn., Bull. B-22, 66 p.

Gray, G. G.
1975. Non-consumptive demand for wildlife by municipal conservation commissions in Massachusetts. M.S. thesis, 94 p. Univ. Mass., Amherst.

Greene, Jeffrey C.
1970. Characteristics of some Michigan shooting preserve users. J. Wildl. Manage. 34(4):813-817.

Gum, R. L., W. E. Martin, A. H. Smith, and C. D. Depping
1973. Participation and expenditures for hunting, fishing and general rural outdoor recreation in Arizona. Res. Rep. 270, 22 p. Ariz. Agric. Exp. Stn.

Hansen, Lars, and Randy T. Simmons
1974. Public opinion survey of fishing and hunting activities in Utah. Bur. Gov. and Opin. Res. Utah State Univ. Publ. No. 74-14, 93 p.

Haulsee, Hada V., Enoch Bell, Emmett F. Thompson, and Alfred D. Sullivan
1973. Management implications of deer hunter attitudes. Proc. Northeast Sec. Wildl. Soc. 12 p.

Hendee, John C.
1967. Recreation clientele--the attributes of recreationists preferring different management agencies, car campgrounds or wilderness in the Pacific Northwest. Ph. D. diss., Univ. Wash., Seattle.

Hendee, John C.
1974. A multiple-satisfaction approach to game management. Wildl. Soc. Bull. 2(3):104-113.

endee, John C., William R. Catton, Jr., Larry D. Marlow, and C. Frank Brockman
1968. Wilderness users in the Pacific Northwest--their characteristics, values, and management preferences. USDA For. Serv. Res. Pap. PNW-61, 92 p.

endee, John C., Richard P. Gale, and Joseph Harry
1969. Conservation, politics, and democracy. J. Soil and Water Conserv. 24(6):212-215.

Hendee, John C., and Dale R. Potter
1971. Human behavior and wildlife management: needed research. Trans. 36th North Am. Wildl. Nat. Resour. Conf. 36:383-396.

Horvath, Joseph
1974. Southeastern detailed analysis economic survey of wildlife recreati Environ. Res. Group, Ga. State Univ.

James, George A., Harold K. Cordell, Frank B. Barick, and Robert L. Downing
1969. Small game hunting on western North Carolina wildlife management areas. Part I - Characteristics of hunters. Wildl. N.C. 33(10):8-10.

Jamsen, G. C.
1967. Sex and age structure of licensed hunters, trappers and fishermen in Michigan. Mich. Dep. Conserv. Res. Dev. Rep. No. 125, 14 p.

Kellert, Stephen R.
1974. From kinship to mastery: A study of American attitudes toward animals. Report to Fish and Wildlife Service. U.S. Dep. Inter., 216 p.

Kennedy, James J.
1974. Attitudes and behavior of deer hunters in a Maryland forest. J. Wildl. Manage. 38(1):1-8.

Kirkpatrick, Thomas O.
1965. The economic and social values of hunting and fishing in New Mexico. Univ. N.M. Bur. Bus. Res. 94 p., illus.

Klessig, Lowell L.
1970. Hunting in Wisconsin: initiation, desertion, activity patterns, and attitudes as influenced by social class and residence. M.S. thesis, 152 p. Univ. Wis.

Klessig, Lowell L., and James B. Hale
1972. A profile of Wisconsin hunters. Tech. Bull. No. 60, 24 p. Wis. Dep. Nat. Resour., Madison.

Leopold, Aldo
1949. A sand county almanac. 295 p. Oxford Univ. Press.

Lobdell, Charles H.
1967. Socio-economic characteristics of Maine sportsmen. M.S. thesis, 95 p. Univ. Maine.

Moncrief, Lewis Whitfield
1970. An analysis of hunter attitudes toward the State of Michigan's antlerless deer hunting policy. Ph. D. diss., 258 p. Mich. State Univ.

More, Thomas A.
1973. Attitudes of Massachusetts hunters. Proc. 38th North Am. Wildl. Nat. Resour. Conf. Reprinted in Human dimensions in wildlife programs, ed. by John C. Hendee and Clay Schoenfeld, p. 72-126. Wildl. Manage. Inst.

Nobe, Kenneth C., and Alphonse H. Gilbert
1970. A survey of sportsmen expenditures for hunting and fishing in Colorado, 1968. Colo. Div. Game, Fish and Parks GFP-R-T-24, 83 p.

Noges, John H., and Donald R. Progulske (ed.)
1974. Wildlife in an urbanizing environment. Plann. and Resour. Dev. Ser. 28, 182 p. Holdsworth Nat. Resour. Cent. Univ. Mass., Amherst.

Outdoor Recreation Resources Review Commission
1960. National recreation survey. Outdoor Recreation Resour. Rev. Comm. Study Rep. 19, p. 8-54.

Palmer, Walter L.
1966. An analysis of the public use of southern Michigan game and recreation areas. Ph. D. diss., 131 p. Mich. State Univ.

Payne, Brian R., and Richard M. DeGraaf
1975. Economic values and recreational trends associated with human enjoyment of non-game birds. In Proceedings of the Symposium on management of forest and range habitats for non-game birds. USDA For. Serv. Gen. Tech. Rep. WO-1, p. 6-10.

Peterle, Tony J.
1961. The hunter--who is he? 26th Conf. North Am. Wildl. Nat. Resour. Trans. 26:254-266, illus.

Peterle, Tony J.
1967. Characteristics of some Ohio hunters. J. Wildl. Manage. 31(2):375-389.

Peterson, William J.
1969. A literature review of deer harvest. Colo. Div. Game, Fish and Parks and Coop. Wildl. Unit, Spec. Rep. No. 22, 15 p.

Poole, Daniel A.
1964. How many hunters? Am. Rifleman 112(1):15-18.

Poole, Daniel A.
1971. Insuring the future of hunting and fishing. Wildl. Soc. News (136):1, 46.

Potter, Dale, R. Kathryn M. Sharpe, and John C. Hendee
1973a. Human behavior aspects of fish and wildlife conservation: An annotated bibliography. USDA For. Serv. Gen. Tech. Rep. PNW-4, 288 p.

Potter, Dale, John C. Hendee, and Lee E. Evison
1973b. Hunters at regulated plant-and-shoot pheasant areas in western Washington. USDA For. Serv. Res. Pap. PNW-160, 30 p.

Potter, Dale, John C. Hendee, and Roger N. Clark
1973c. Hunting satisfaction: game, guns, or nature. Proc. 38th North Am. Wildl. Natur. Resour. Conf. Reprinted in Human dimensions in wildlife programs, ed. by John C. Hendee and Clay Schoenfeld, p. 62-76. Wildl. Manage. Inst.

Ryel, L. A.
1971. Deer hunters participation survey, 1970. Mich. Dep. Nat. Resour. Res. and Dev. Rep. No. 254, 11 p.

Ryel, L. A., G. C. Jamsen, and L. J. Hawn
1970. Some facts about Michigans hunters. Mich. Dep. Nat. Resour. Res. Dev. Rep. No. 197, 25 p.

Schole, Bernard J.
1973. A literature review on characteristics of hunters. Spec. Rep. No. 33. Colo. Div. Wildlife. 15 p. State Publ. Code GFP-R-S-33.

Schole, Bernard J., Fred Glover, Douglas Sjogren, and Eugene Decker
1973. Colorado hunter behavior attitudes and philosophies. Proc. 38th North Am. Wildl. Resour. Conf. Reprinted in Human dimensions in wildlife programs, ed. by John C. Hendee and Clay Schoenfeld, p. 84-90. Wildl. Manage. Inst.

Schweitzer, Douglas H., David A. Scott, Arthur W. Blue, and Jonathan Secter
1973. Recreational preferences for birds in Saskatchewan. Proc. 38th North Am. Wildl. Nat. Resour. Conf. Reprinted in Human dimensions in wildlife programs, ed. by John C. Hendee and Clay Schoenfeld, p. 42-50. Wildl. Manage. Inst.

Sendak, Paul E., and Robert S. Bond
1970. A consumer analysis of licensed hunters and fishermen in Massachusetts. Holdsworth Nat. Resour. Cent., Univ. Mass. 43 p. Planning Resour. Dev. Ser. No. 14. Bull. No. 583.

Shaw, Dale L.
1973. The hunting controversy: attitudes and arguments. Ph. D. diss., 174 p. Colo. State Univ.

Shaw, William W.
1974. Sociological and psychological determinants of attitude toward hunting. Ph. D. diss., 84 p. Univ. Mich.

Slater, Daniel W.
1972. Review of the 1970 national survey. Trans. Am. Fish. Soc. 101(1): 163-167.

Sofranko, Andrew J., and Michael F. Nolan
1970. Selected characteristics, participation patterns, and attitudes of hunters and fishermen in Pennsylvania. Agric. Exp. Stn. Pa. State Univ. Bull. 770, 39 p.

Stankey, George H., Robert C. Lucas, and Robert R. Ream
1973. Relationships between hunting success and satisfaction. Proc. 38th North Am. Wildl. Nat. Resour. Conf. Reprinted in human dimensions in wildlife programs, ed. by John C. Hendee and Clay Schoenfeld, p. 77-84. Wildl. Manage. Inst.

Thomas, Jack Ward, and James C. Pack
1968. Joe typical-profile of a hunter. Outdoor W. Va. 32:19-20.

U.S. Bureau of Outdoor Recreation
1971. Selected outdoor recreation statistics. U.S. Dep. Inter. 145 p.

U.S. Department of Agriculture
1975. Proceedings of the symposium on management of forest and range habitats for non-game birds. USDA For. Serv. Gen. Tech. Rep. WO-1, 343 p.

U.S. Department of the Interior
1956. National survey of fishing and hunting 1955. Fish and Wildl. Serv. Circ. 44, 50 p.

U.S. Department of the Interior
1961. 1960 national survey of fishing and hunting. Fish and Wildl. Serv. Circ. 120, 73 p.

U.S. Department of the Interior
1967. 1965 national survey of fishing and hunting. Fish and Wildl. Serv. Res. Publ. 27, 76 p.

U.S. Department of the Interior
1972. National survey of fishing and hunting 1970. Fish and Wildl. Serv. Res. Publ. 95, 108 p.

U.S. Department of the Interior
1975. Record numbers of Americans hunt and fish. News release, May 25. Fish and Wildl. Serv.

U.S. Study Commission, Southeast River Basins
1963. Plan for development of the land and water resources of the southeast river basins. Appendix 12--planning. p. 2-101. Southeast River Basins Comm.

Vaux, H. J., Jr.
1975. The distribution of income among wilderness users. J. Leisure Res. 7(1):29-37.

Watson, Marvan H., Gale C. Jamsen, and Lewis W. Moncrief
1972. The Michigan deer hunter. Mich. Dep. Nat. Resour. Res. Dev. Rep. No. 259, 33 p.

Wildlife Management Institute
1973. National survey of State fish and wildlife funding. 40 p. Wildl. Manage. Inst., Washington, D.C.

Zimmerman, Donald E.
1968. Determination of the sources of conservation information and characteristics of selected Kansas sportsmen. M.S. thesis, 102 p., illus. Kans. State Univ.

Appendix 1.--Hunter study description

Location of study	Population studied	Year studied	Publication citation	Usable response	Percent response rate	Study method
Arizona	Hunters and fishermen	1960	Davis (1962)	1,029	--	Interview
Arizona	Hunters and fishermen	1965	David (1967)	1,000	--	Interview
Arizona	Hunting and fishing households	1970	Gum et al. (1973)	2,985	19.9	Mail questionnaire
California	Hunters	1959-60	Folkman (1963)	3,260	31	Mail questionnaire
Colorado	Hunters and fishermen	1966-67	Nobe and Gilbert (1970)	1,865	--	Interview
Kansas	Fish/game magazine readers and Wildlife Federation members	1967	Zimmerman (1968)	363	68.5	Mail questionnaire
Maryland	Deer hunters	1969	Kennedy (1974)	373	82	Mail questionnaire
Massachusetts	Hunters	1970	More (1973)	325	69.6	Mail questionnaire
Massachusetts	Hunters and fishermen	1965	Sendak and Bond (1970)	1,070	64.3	Mail questionnaire
Michigan	Hunters	1966	Jamsen (1967)	12,425	--	Agency records
Michigan	Preserve hunters	1969	Greene (1970)	241	71	Questionnaire
Michigan	Deer hunters	1968	Ryel et al. (1970)	--	--	Miscellaneous
Michigan	Deer hunters	1968	Moncrief (1970)	336	85	Interview
Michigan	Deer hunters	1966 and 1968	Ryel (1971)	336	93.9	Questionnaire
Michigan	Deer hunters	1971	Haulsee et al. (1973)	3,513	67	Mail questionnaire
Nevada	Hunters	1967-68	Garrett (1970)	--	--	Mail questionnaire
New Mexico	Hunters and fishermen	1963	Kirkpatrick (1965)	3,648	53	Mail questionnaire
North Carolina	Small game hunters	1964-65	James et al. (1969)	445	--	Interview
Ohio	Hunters	1959	Peterle (1961)	1,100	59.2	Mail questionnaire
Pennsylvania	Hunters	1965	Sofranko and Nolan (1970)	318	77.2	Mail questionnaire
Texas	Hunters	1972-73	Berger (1974)	1,581	46.4	Mail questionnaire
Utah	Elk hunters	1966	Ashcroft (1967)	517	41	Questionnaire
Washington	Pheasant hunters	1971	Potter et al. (1973b)	1,062	87.3	Mail questionnaire
Washington	All Washington hunters	1971	Potter et al. (1973c)	5,540	85	Mail questionnaire
West Virginia	Hunters	1967	Thomas and Pack (1968)	1,353	--	Interview
Wisconsin	Hunters	1968	Klessig and Hale (1972)	1,035	69	Mail questionnaire
Wyoming	Resident big game hunters	1970	Doll and Phillips (1972)	--	--	Mail questionnaire
Northeast[a/] (6 States)	Hunters	1965	Bevins et al. (1968)	6,589	69	Mail questionnaire
Southeast[b/] (11 States)	Hunters	1971	Horvath (1974)	9,332	77.25	Interview
National	All hunters	1955	U.S. Department of the Interior (1956)	--	--	Interview
National	All hunters	1961	U.S. Department of the Interior (1961)	--	--	Interview
National	All hunters	1965	U.S. Department of the Interior (1967)	--	--	Interview
National	All hunters	1972	U.S. Department of the Interior (1972)	--	--	Interview

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[a/] Maine, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia.

[b/] Arkansas, east Texas, Georgia, Kentucky, Louisiana, Maryland, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia.

Appendix 2.--Age distribution from 20 studies in 14 States and 1 regional study

Location	Year studied	Population studied	Citation	Hunter age in years													Total percent
				5	10	15	20	25	30	35	40	45	50	55	60	65 and older	
				Percent													
Arizona	1960	Hunters and fishermen	Davis (1962)		12.6		8.5	22.0		26.6		17.9		8.6		3.5	100
Arizona	1965	Hunters and fishermen	Davis (1967)		12.0		6.6	18.7		25.8		20.5		12.4		3.8	100
California	1959-60	Hunters	Folkman (1963)	2.2		8.8	6.4	8.3	13.5	14.8	13.4	10.8	8.4	6.3	3.0	3.5	99[a]
Colorado	1966	Hunters and fishermen	Nobe and Gilbert (1970)	15.8					27.9		28.2		17.1		11.0		100
Maine	1965	Hunters and fishermen	Lobdell (1967)		10.8		19.1		21.2		19.5		16.1		13.3		100
Massachusetts	1965	Hunters	Sendak and Bono (1970)	23.0		22.0		20.0		16.0		10.0		5.0		4.0	100
Michigan	1966	Deer hunters	Jamsen (1967)	7.0		8.2	11.5	12.0	11.1	10.5	9.9	8.9	7.3	5.3	4.0	4.3	100
Michigan	1968	Deer hunters	Ryel et al. (1970)	0	2	14	12	13	11	10	10	8	7	6	4	4	101[a]
Michigan	1968	Deer hunters	Ryel (1971)		3	9	11	13	11	10	8	10	8	5	5	3	96[a]
Michigan	1967	Deer hunters	Watson et al (1972)		23			24		22		15		12		4	100
New Mexico	1963	Hunters	Kirkpatrick (1965)	1	5	12	11	27		26		17				1	100
North Carolina	1964-65	Small game hunters	James et al. (1969)		21				25		27		18		9		100
Northeast (6 States)[b]	1965	Hunters	Bevins et al. (1968)	13			24		21		19		13		10		100
Ohio	1959	Hunters	Peterle (1961)		10	17		20		22	31						100
Texas	1973	Hunters	Berger (1974)	3			24		25		23		18		7		100
Washington	1971	Pheasant hunters	Potter et al. (1973b)	15			11	28		21		21				4	100
Washington	1971	Hunters	Potter et al. (1973b)	17			11	24		19		25				4	100
West Virginia	1967	Hunters	Thomas and Pack (1968)	12			84								4		100
Wisconsin	1968	Hunters	Klessig and Hale (1972)		20		28		18		15		11		8		100
Wyoming	1970	Big game hunters	Doll and Phillips (1972)			15	8	10	21		13		21			7	100

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[a] Data reported in study did not total 100 percent.

[b] Maine, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia

Appendix 3 --Levels of hunter education from 18 studies in 12 States, 2 regional, and 2 national surveys. Circled percentages indicate the exact proportion under that category

Location	Year studied	Population studied	Citation	Less than high school graduate			High school graduate		Some college		College graduate		Post graduate				Total percent
				Years of schooling													
				8	9	10	11	12	13	14	15	16	17	18	19	20	
				Percent													
Colorado	1966-67	Hunters and fishermen	Nobe and Gilbert (1970)		20				47			24			9		100
Maine	1965	Hunters and fishermen	Lobdell (1967)		46			㉞		14				6			100
Massachusetts	1965	Hunters	Sendak and Bond (1970)		37			㉟		18		⑦		3			100
Michigan	1969	Preserve hunters	Greene (1970)		14					44				42			100
Michigan	1967	Deer hunters	Watson et al (1972)		38			㊲		17		③		5			100
National	1965	Hunters	U.S. Department of the Interior (1967)		43			㊳		10				9			100
National	1970	Hunters	U.S. Department of the Interior (1972)		40			㊲		11		⑦		5			100
New Mexico	1963	Big game hunters	Kirkpatrick (1965)		44			㉘		15		⑥		7			100
North Carolina	1964-65	Small game hunters	James et al. (1969)	32		18		36		6		2		6			100
Northeast (6 States)a/	1965	Hunters	Bevins et al. (1968)		41			㊲		13				9			100
Ohio	1959	Hunters	Peterle (1961)		41			㊿		3				6			100
Pennsylvania	1965	Hunters	Sofranko and Nolan (1970)	17		69				6				7			99b/
Southeast (11 States)c/	1971	Hunters	Horvath (1974)	13	24				42			18			3		100
Texas	1973	Hunters	Berger (1974)		15			㉔		35		⑮		10			99b/
Washington	1971	Pheasant hunters	Potter et al. (1973b)		23			㉟		22		⑪		10			101b/
Washington	1971	Hunters	Potter et al. (1973b)		33			㊲		18		⑥		5			99b/
Wisconsin	1968	Hunters	Klessig and Hale (1972)		25			㊶		13		⑫		9			100
Wyoming	1970	Big game hunters	Joll and Phillips (1972)		26			㉜		20		⑫		10			100

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a/ Maine, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia.

b/ Data reported in study did not total 100 percent

c/ Arkansas, east Texas, Georgia, Kentucky, Louisiana, Maryland, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia.

Appendix 4.--Hunter occupations from 22 studies in 13 States and 2 regional studies

Location	Year studied	Population studied	Citation	White collar	Sales, kindred	Blue collar laborers	Service	Agricultural	Retired	Student	Unemployed	Other	Total percent
				- - - -	- - - -	- - - -	- - - -	Percent	- - - -	- - - -	- - - -	- - - -	
Arizona	1960	Hunters and fishermen	Davis (1962)	28	5	49	5	5				9	101[a]
Arizona	1965	Hunters and fishermen	Davis (1967)	25	7	45	9	4				10	100
California	1959-60	Hunters	Folkman (1963)	18	10	38	5	6	3	10	1	9	100
Colorado	1966-67	Hunters and fishermen	Nobe and Gilbert (1970)	37	6	43		4	7	1		2	100
Maine	1965	Hunters and fishermen	Lobdell (1967)	12	29	44	(see Sales)					15	100
Massachusetts	1965	Hunters and fishermen	Sendak and Bond (1970)	24	14	40	13	2				7	100
Michigan	1969	Preserve hunters	Greene (1970)	53	14	19	6	0	1	←	7	→	100
Michigan	1962-66	Deer hunters	Ryel (1971)	14	4	50	6	4	6	11	1	3	99[a]
Michigan	1968	Deer hunters	Moncrief (1970)	32		52		3	←	13		→	100
New Mexico	1963	Hunters and fishermen	Kirkpatrick (1965)	←		87		→	←	13		→	100
Northeast (6 States)[b]	1965	Hunters	Bevins et al. (1968)	15	12	42	12	7				12	100
Ohio	1959	Hunters	Peterle (1961)	13	4	56	9	6		12			100
Pennsylvania	1965	Hunters	Sofranko and Nolan (1970)	13	13	42	9	6				17	100
Southeast (11 States)[c]	1971	Hunters	Horvath (1974)	30	5	38	5	8	9	1	2	3	101[a]
Texas	1973	Hunters	Berger (1974)	54		16		6	←	12		→	88[a]
Washington	1971	Pheasant hunters	Potter et al. (1973b)	31	10	30		2	6	14		7	100
Washington	1971	Hunters	Potter et al. (1973b)	20	9	39		3	6	17		6	100
Wisconsin	1968	Hunters	Klessig and Hale (1972) Klessig (1970)	19	4	41	3	8		25			100
Wyoming	1970	Big game hunters	Doll and Phillips (1972)	40	3	31	5	14	3	2		2	100

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[a] Data reported in study did not total 100 percent.

[b] Maine, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia.

[c] Arkansas, east Texas, Georgia, Kentucky, Louisiana, Maryland, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia.

Appendix 5.--Percent income Distribution from 18 studies in 13 States and 2 regional studies

Location	Year studied	Population studied	Citation	Income in thousands of dollars (5, 10, 15, 20, 25, 30, 35 and above)	Total percent
Arizona	1960	Hunters and fishermen	Davis (1962)	8 | 17 | 34 | 24 | 10 | 5	98[a]
Arizona	1965	Hunters and fishermen	Davis (1967)	6 | 9 | 28 | 31 | 18 | 8	100
Colorado	1966	Hunters and fishermen	Nobe and Gilbert (1968)	6 | 5 | 26 | 8 | 25 | 14 | 16	100
Maine	1965	Hunters and fishermen	Lobdell (1967)	13 | 17 | 26 | 16 | 11 | 6 | 3 | 8	100
Massachusetts	1965	Hunters and fishermen	Sendak and Bond (1970)	9 | 13 | 29 | 24 | 10 | 6 | 3 | 6	100
Michigan	1969	Preserve hunters	Greene (1970)	2 | 15 | 23 | 28 | 32	100
Michigan	1968	Deer hunters	Moncrief (1970)	4 | 4 | 19 | 27 | 28 | 8	90[a]
New Mexico	1963	Big game hunters	Kirkpatrick (1965)	8 | 18 | 28 | 29 | 13 | 3 | 1	100
North Carolina	1964-65	Small game hunters	James et al. (1969)	27 | 31 | 30 | 9 | 3	100
Northeast (6 States)[b]	1965	Hunters	Bevins et al. (1968)	11 | 17 | 28 | 20 | 11 | 6 | 2 | 5	100
Ohio	1959	Hunters	Peterle (1961, 1967)	22 | 24 | 35 | 11 | 8	100
Pennsylvania	1965	Hunters	Sofranko and Nolan (1970)	11 | 15 | 28 | 21 | 13 | 4 | 8	100
Southeast (11 States)[c]	1971	Hunters	Horvath (1974)	11 | 13 | 16 | 21 | 20 | 8 | 3 | 4	96[a]
Texas	1972	Hunters	Berger (1974)	6 | 21 | 33 | 18 | 10 | 4 | 2 | 6	100
Washington	1971	Pheasant hunters	Potter et al. (1973b)	7 | 15 | 31 | 21 | 11 | 15	100
Washington	1971	Hunters	Potter et al. (1973b)	13 | 21 | 29 | 18 | 8 | 10	99[a]
Wisconsin	1968	Hunters	Klessig and Hale (1972), Klessig (1970)	12 | 10 | 21 | 18 | 18 | 12 | 9	100
Wyoming	1970	Big game hunters	Doll and Phillips (1972)	5 | 11 | 25 | 31 | 18	90[a]

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[a] Data reported in study did not total 100 percent.

[b] Maine, Massachusetts, New York, Pennsylvania, Vermont, and West Virginia.

[c] Arkansas, east Texas, Georgia, Kentucky, Louisiana, Maryland, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia.

Appendix 6.--Hunter and hunter childhood residence from 16 studies in 13 States and 1 regional study

Location	Year studied	Population studied	Citation	Hunter residence		Childhood residence	
				Rural	Urban	Rural	Urban
				Percent			
California	1959-60	Hunters	Folkman (1963)	33.3	67.4		
Maine	1965	Hunters	Lobdell (1967)			78.1	21.9
Maryland	1969	Deer hunters	Kennedy (1974)	33.0	67.0	44.0	56.0
Massachusetts	1965	Hunters	Sendak and Bond (1970)			58.0	42.0
Michigan	1961-62	Hunters	Palmer (1966)			60.0	40.0
Michigan	1969	Preserve hunters	Greene (1970)				
New Mexico	1963	Hunters and fishermen	Kirkpatrick (1965)	37.8	62.2		
North Carolina	1964-65	Small game hunters	James et al. (1969)	64.0	36.0		
Ohio	1959	Hunters	Peterle (1961)			58.0	42.0
Pennsylvania	1965	Hunters	Sofranko and Nolan (1970)			69.4	30.6
Southeast (11 States)[a]	1971	Hunters	Horvath (1974)	61.2	38.8		
Texas	1973	Hunters	Berger (1974)	33.7	66.3	62.4	37.5
Washington	1971	Pheasant hunters	Potter et al. (1973b)	49.0	51.0		
Washington	1971	Hunters	Potter et al. (1973b)	70.0	30.0		
Wisconsin	1968	Hunters	Klessig (1970)			62.0	38.0
Wyoming	1970	Big game hunters	Doll and Phillips (1972)	32.0	68.0		

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[a] Arkansas, east Texas, Georgia, Kentucky, Louisiana, Maryland, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia.

TOPIC IV

SOCIAL AND INSTITUTIONAL CONSIDERATIONS

ABSTRACTS

DRIVER

Toward a Better Understanding of the Social Benefits of Outdoor Recreation Participation.--This paper proposes that recreation resource managers need to give more attention to the benefits that a person derives from participation in recreation activities. Behavioral information is described as one of several types of knowledge needed in recreation planning and management decisions. A model outlining the dynamics of a recreationist's behavior is presented. Within that model sequences of specific types of recreation behavior are traced from: deciding on a particular recreation activity, planning and preparation, on-site engagement, recall, realizing satisfying experiences, to gaining the ultimate benefits these experiences can produce. Personal and social benefits of recreation participation are defined as the ways in which an individual functions or performs more effectively because of his having participated in a recreation activity. The importance to recreation resource management of information on these benefits is described as is the stage of knowledge for identifying and measuring them. Throughout, the need for additional research is emphasized.

ERICKSON AND DAVIS

Public Involvement in Recreation Resources Decision Making.--In response to legal and administrative requirements, federal natural resource agencies are involving citizens in the decision making process. However, given the arguments stated both for and against public involvement, one might raise a question about the proper role of involvement in agency decision making. While twelve general principles of public involvement and a number of relatively new public involvement techniques, e.g., public information brochure, nominal group and Delphi, are discussed, research has not progressed to the point where "formulas" for involvement can be given. Agency cooperation is vitally needed to permit a comparative evaluation of alternative techniques.

LAPAGE

New Roles for Government and Industry in Outdoor Recreation.--The examination of some possible future options for public parks and recreation agencies is necessitated by 3 hard facts: 1. the rising dominance of the private sector, 2. the emerging public revolt against increased tax supported programs, and 3. the trend toward greater public involvement in agency decision-making. A central role for public parks and recreation agencies is seen to be that of a cooperator with the private sector, taking such forms as joint development planning, increased use of concession-operated public facilities, and new directions for public parks and recreation programs.

TOWARD A BETTER UNDERSTANDING OF THE SOCIAL BENEFITS OF OUTDOOR RECREATION PARTICIPATION

B. L. Driver[1/]

Abstract.--This paper proposes that recreation resource managers need to give more attention to the benefits that a person derives from participation in recreation activities. Behavioral information is described as one of several types of knowledge needed in recreation planning and management decisions. A model outlining the dynamics of a recreationist's behavior is presented. Within that model sequences of specific types of recreation behavior are traced from: deciding on a particular recreation activity, planning and preparation, on-site engagement, recall, realizing satisfying experiences, to gaining the ultimate benefits these experiences can produce. Personal and social benefits of recreation participation are defined as the ways in which an individual functions or performs more effectively because of his having participated in a recreation activity. The importance to recreation resource management of information on these benefits is described as is the state of knowledge for identifying and measuring them. Throughout, the need for additional research is emphasized.

Keywords: recreation benefits, recreation aspirations, recreation experiences.

This paper is addressed to three questions: (1) Why should recreation resource planners and managers give more attention to the human benefits "produced" from recreation opportunities? (2) How can information on these benefits be obtained? and (3) How does this behavioral information fit with the other types needed in planning and management?

The word "benefit" is used in reference to how participation in recreation activities enhances or imporves the user's ability to function more effectively after having participated. Such improved functioning could be physiological (better physical health), psychological (improved mental health) or sociological (increased commitments of recreationists to wise resource management because of knowledge gained from participation). Also, the improvements in effective functioning could be realized on the job (greater volume or increased quality of work accomplished), at home (increased family solidarity), or in any environment.

The words "recreation experiences" are used in a context that should be explained. At a broad level, a recreation experience is the sum of a participant's mental, spiritual, physiological or other responses to a recreational engagement. Such an overall experience might be satisfying or pleasurable,

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or it might not be satisfying; there are "bad" as well as"good" experiences. At this broad level there are general activity-dependent experiences, such as a white-water canoeing experience for example. This general experience would include all responses from anticipation to recall (Clawson and Knetsch 1966). At a narrower level there are several specific experiences associated with participation in a particular activity. These specific experiences help define the attractiveness of an activity or environment to a particular user group and the type of satisfaction realized from that activity. In white-water canoeing, specific experiences could include: taking risks, testing skills, being with like-minded associates, exercising, enjoying nature, displaying equipment, introspecting-seeking privacy, or avoiding temporarily a problem experienced back home or on the job. These might be called the specific attributes that define a general white-water canoeing experience. Each will be giving satisfaction (or dissatisfaction) simultaneously, but some will be more satisfying than others.[2] For that reason potential white-water canoers will value some of these specific experiences higher than others when deciding whether or not to make a white-water canoeing trip.

Some specific experiences are highly dependent on the characteristic of the physical resources (fast water). Others are more dependent on the facilities or equipment (sturdy canoes) and still others on the characteristic of the users (personality trait, age, sex, etc...; or interpersonal things such as a desire to win the approval of others). The degree of "resource-dependency" varies between activities. For example, some experiences (matching wits with a trophy deer, skillfully negotiating the rapids, learning about prehistoric man, enjoying a spectacular view) are more dependent on the physical resources than are others (being with friends, exercising, general nature learning, etc.). The trick in management is to allocate the resources to their highest potential for providing opportunities for specific desired experiences and their consequent human benefits.

PURPOSES

The tasks assigned for this paper were:

1. To describe the state of knowledge for identifying and measuring the personal-social benefits of recreation,[3]
2. To interpret the relevancy of that body of knowledge for recreation resource planning and management, expecially those operating in the public sector, and
3. To outline important research needs on that subject.

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[2] Elsewhere, these simultaneously occurring experiences have been identified as a "package of experiences" (Driver and Tocher, 1974) and as "multiple satisfactions" (Hendee 1974).

[3] The words "personal" and "social" benefits are used interchangeably in the paper. Alternative words could be "private" benefits (to the user) and "collective" benefits (to others because of an individual's participation) so long as enhanced effective performance of the participant (or of others) is the criterion.

The first task is both easy and impossible. It is easy to say that the state of the art is in its embryonic stage because relatively little research has been directed at quantification of recreation benefits. This "easy out" begs the question, though. Many theories and methods in the behavioral sciences are applicable to the subject of this paper even though few of these applications have been made. It is an impossible task, however, to consider the many diverse theories of human behavior which can be interpreted with respect to what they might say about man's beneficial psychological, physiological or sociological responses to recreational engagement. These theories range from Freud's (1955) and Piaget's (1962) thoughts on the value of play in social and cognitive development through Berlyne's (1960, 1969) concepts regarding arousal seeking and exploratory preferences to the work of physiologists and parapsychologists on relationships between mind control techniques and physical-mental relaxation.

Because of the complexity of the subject, this paper will describe only one approach to identifying and measuring the personal-social benefits of recreation and discuss briefly the state of knowledge about that approach. That approach has been followed in recent years by a growing number of researchers who feel it is theoretically realistic, managerially relevant and relatively easily understood by managers who do not have intensive training in the social or human behavioral sciences. Briefly, the approach adopts the view that most human behavior is purposeful, in that recreationists select particular activities because of the satisfying experiences they expect and desire from that activity.

Future research needs are a part of the discussion because of the limited number of studies conducted so far on recreation benefits. Throughout, the importance to managers of information on recreation benefits is emphasized. Also, footnotes are used frequently to qualify concepts that might be novel and to help avoid possible misinterpretation.

WHY CONSIDER PERSONAL BENEFITS?

Numbers of visitors to outdoor recreation areas have increased by greater than a 5 percent compound annual rate for the past several decades. In the most recent years, the rate has been even higher, up to 15 to 20 percent, for specific areas and activities such as back-country and lift skiing. These are interesting statistics when compared with selected baseline social indicators. Increases in population and personal disposable income have both increased at less than 3 percent per year, and per capita consumption of energy (in BTU's) has increased at less than 5 percent during the past decade.

Despite these trends in use and the fact that each year more resources are allocated to supply additional recreation opportunities, we do not have adequate measures of the social costs and benefits of these allocations.

This paper does not consider the costs or all of the different types of benefits. Instead, it focuses on a particular type of benefit which is defined behaviorally in terms of user response.[4] The major thesis is that, within this behavioral perspective, several limitations in knowledge are especially constraining. In particular, more objective measures are needed of the following four related sets of variables:

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[4] In addition to the increased effective functioning of the recreationists, other benefits of recreation allocations could include: local income benefits; benefits to animal species from hunting-generated revenues; and preservation of options for future generations to benefit.

1. The attributes (or characteristics) of the physical (and social) setting that are perceived by potential users to be necessary for a quality recreation experience.

2. The type and number of recreation experiences sought from specific recreation environments both on-site and by "appreciative" off-site users, who enjoy the existence of these opportunities and desire to preserve the options for possible on-site engagement by themselves or others.

3. The characteristics of potential and actual recreationists having demands for different types of recreation experiences and the cause-effect relationships between these characteristics and recreation demand.

4. The personal experiences and benefits realized from specific recreation opportunities.

Such measures would not be needed in recreation planning and management if our intuitions and judgments about recreation aspirations, experiences and benefits are realistic. Past studies have indicated, however, that the managers' intuitions and the users' opinions about the recreational values of the facilities frequently differ (Lucas 1964, Hendee and Harris 1970, Clark et al. 1971, and Peterson 1971 and 1974b).

In the past, policy makers and planners have had to define these values intuitively because there was little else to go on. And they have done a good job, given the budgets and the complexity and uncertainty within which they were working. However, as the demands grow for all of the goods and services produced by our nation's natural resources, more objective measures are needed; in the face of this increased relative scarcity managers no longer have the room for error they once did in their decision processes.

Objective measures of recreation values are especially needed in allocation decisions to compare the social benefits and costs of different types of recreation opportunities and the values receivable from alternative uses. For example, past measures of the outputs of recreation areas have used variables such as numbers of visitors and visitor days. Although necessary in planning and management decisions, these variables are little more than counts of people using the system and do not tell us much about the number, type and magnitude of benefits produced. The major problem is that counts of users are of too little value in defining managerial objectives (or even policy guidelines) about what specifically is to be produced or in evaluating the degree to which these objectives are realized. It is hard to "manage by objectives" when realistic, relevant and quantifiable targets cannot be set to measure accomplishments. And numbers of users are not completely adequate targets.

By analogy, we have a better understanding of what other social service "systems" (education, sanitation, communication, housing, transportation and medicine) are "doing for" the users of those services. For example, if counts of users were the primary guide for the administration of colleges, common management operations would become less relevant. These would include establishing entrance requirements, screening faculty, designing curricula, administering qualifying exams and maintaining standards for certification. Each of these operations exists to help assure a quality product rather than to accommodate as many students as possible.

What is being suggested is that the management of recreation resources is a production process, as is timber management, wildlife management and watershed management. The problem is that the "products" of recreation management are harder to define.[5] Nevertheless, we need to go beyond the conventional wisdom that the product of recreation management is recreation opportunities and identify more clearly what it is that these opportunities do for the user. This idea has been elaborated elsewhere (Hendee 1974, Driver and Brown 1975)[6].

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[5] This inadequate definition of the social values of recreation has probably contributed to the view that recreation goods and services are of less relative importance to society than are other goods and services that compete locally and nationally for scarce budgets and other resources. For example, established recreation areas are frequently converted to housing, sewer, and highway developments.

[6] It is beyond the scope of this paper to elaborate on the additional relevance to management of better information on user expectations, experiences and benefits. It might be useful to footnote, however, that this information is fundamental to the resolution of several problems within the field of outdoor recreation resource management. These include: (1) identifying more clearly what recreational benefits can (and should) be produced most appropriately by different public and private agencies; (2) defining better the "merit good" aspects of recreation behavior (i.e., to what degree does one person's recreation participation benefit other people who do not participate) in an attempt to help identify the degree to which specific opportunities should be financed through taxation by all users who benefit either directly or indirectly or alternatively through user prices, when benefits are limited primarily to the participants; (3) determining relationships between recreation behavior and "off-system" variables such as those defining the users' home and work environments; (4) defining latent demands of those potential users not included in statistics on past use rates; (5) identifying and appraising trade-offs and substitutibilities between different recreation activities and between recreation and other uses of the same resources; (6) determining the probable "performance" of physical-resource settings in meeting user expectations and classifying the resources for their highest use in terms of experience potential and the resource dependency of these experiences; (7) determining means of reducing conflicts between users with opposing recreation-related demands and appraising the interpersonal-congestion dimensions of area carrying capacity; and (8) evaluating the effectiveness of different visitor management methods such as incentive systems and education.

BUT BEHAVIORAL INFORMATION IS NOT ENOUGH

Despite the importance of behavioral data, it should be emphasized that behavioral information is only one of at least five types of knowledge bases that must be considered by outdoor recreation resource planners and managers (Knopf et al. 1973, Driver 1972). To help iterate this point, it might be useful to group the different types of knowledge bases into five topical sets identified as: Resource-Location, Historical Use, Economic, Administrative-Political, and Behavioral.

Although the five types of knowledge bases are not mutually exclusive, each one does define a rather specific type of information. Also, each group reflects a rather distinct approach to recreation planning and management because each type of information also defines the types of problems for which that information is most relevant. Each will be described briefly:

Resource Location:

Information on the setting and suitability of the physical resources has strongly influenced the kinds and levels of recreation opportunities developed. That information has been obtained from: inventorying, classifying and zoning; appraising the resources within the context of their larger settings; identifying locational relationships, especially distances to centers of population; specifying hazards; and otherwise appraising the recreation resources in terms of their relative scarcity, uniqueness, ecological carrying capacity, and other measures of appropriateness for providing specific recreation opportunities. This type of information defines a supply oriented approach that has been criticized as over-emphasizing supply considerations and slighting demand factors. This might result in creating many similar recreation opportunities on a given resource base within a single region (Twiss 1974). Despite that possible deficiency, this type of information is necessary. However, it can be integrated better with the other four types in recreation planning and management. For example, we might be able to inventory the resources a little better in terms of their potential for providing opportunities for specific recreation experiences or in terms of the resource dependency of specific experiences.

Historical Use:

Descriptive statistical information on past use is relied upon heavily in what could be called the past and current participation approach. Here statistics on past trends of participation "tell" the planner and manager what to do.

The information obtained from this approach has been quite useful in recreation planning. Its five major deficiencies are: (1) it assumes that high levels of participation indicate "successful" planning; (2) it equates past participation with demand and assumes that future demand will follow some historical trend, and thereby, it tends to be self-reinforcing by perpetuating into the future those opportunities which have been supplied in the past, and does not consider latent demand or demand not revealed in past participation (Knetsch 1974); (3) it provides little to no information on substitutibility between activities; (4) it defines recreation as an activity, not as an experience, and therefore offers little insight into the social utility of the opportunities provided; and (5) it nurtures a rather static concept of recreation demand within which explicit questions are not raised about relationships between that demand and changing social conditions, such as energy "crises."

Economic:

In economic terms, recreation resources are viewed as (scarce) economic goods for which there are individual and collective willingnesses to pay. This approach urges particularly for the use of more market-like signals, especially prices, in the allocation of recreation resources. To the extent that the market is unable to do this, the approach calls for the systematic application of principles of public finance in the allocation process. It is concerned with problems relating to the appropriate role of government in bearing the costs of providing recreation opportunities, the efficient level of investment in recreation resource development, and the need for better methods of determining the trade-offs between alternative uses. The data required focus particularly on questions concerning: the benefits and costs of providing different facilities in different locations; the scale of development; the social time preferences for different types of recreation opportunities, and how the opportunities should be financed. The growing relative scarcity of our recreation resources has caused this approach to receive the increased attention it should (Clawson and Knetsch 1966). Some economists, however, fail to recognize sufficiently; (1) several of the deficiencies in their assumptions, such as those regarding existing distributions of income or wealth; (2) the need to sample sub-populations and not rely too strongly on aggregative data; (3) the insufficiencies of the market mechanism; and (4) that other than economic variables must also enter the recreation allocation calculus.

Administrative-Political:

A prudent recreation resource manager certainly must have a reasonable understanding of the administrative-political processes of a democracy. As a general statement, it can be said that the administrative-political approach is one in which primary reliance is placed on the democratic-political process to allocate recreation resources. Under this approach special interests, such as wilderness groups, vie in the political arena for the use of scarce resources according to their preferences. In that arena decisions are made about the rights of future generations of users, the equity of the distribution of opportunities and of tax burdens. Also, the "appropriate" roles of the private and the public sectors are at least discussed if not determined.

Information on recreation resource management is obtained in a variety of ways within this approach. These activities include observing voter behaviors, obtaining information through public involvement and hearings, and analyzing the consequences of interest groups' reliance on the judicial processes. Given the social context within which recreation allocation decisions are made, the practice of pluralism is vital even though it is always accompanied by the potential for the abuse of power, or an inappropriate distribution of such. The information obtained in the other four approaches generally must be processed within the guidelines set by the administrative-political approach.

Behavioral:

Within a behavioral perspective, recreation allocation decisions are not influenced primarily by the inherent capability of physical settings for specific activities, by past trends in use, by the economic characteristics of the resources and its users, or by the administrative-political process. In addition, recreation is viewed as an experience (Driver and Brown 1975).[7] This approach addresses: the reasons why a person participates; what is done while participating; what is derived personally from participation; and the positive and negative influence of environmental factors (including management decisions) on the recreationist's experiences and behavior. Under this approach, recreation demand is for the opportunity to engage in activities from which desired consequences (i.e., satisfying experiences) are expected. Therefore, the demand is for experiences as well as for opportunities. In addition to experiences, the ultimate social services provided by the opportunities are human benefits. The remainder of this paper describes this approach in considerable detail, and it should become apparent that much additional information on recreation behavior is needed. Despite these gaps in knowledge, behavioral information can be integrated better than it has been with the other four knowledge components of management just outlined (Wagar 1964, Burch 1965, Hendee 1971, Brown et al. 1973, Driver and Tocher 1974).

Integration:

The major point of the foregoing discussion is that different problems facing recreation managers require different amounts of each of the five types of knowledge. Another important point is that information from all five knowledge bases needs to be integrated to the extent it is relevant. Thereby, we will help avoid a disciplinary approach to recreation problem solving, which has occurred too frequently, and put more emphasis on an interdisciplinary or multidisciplinary approach.

Certainly, it is no easy task to integrate the relevant knowledge from all five information bases. To do so, recreation planners and managers must have a high degree of technical expertise and work with an interdisciplinary team of technically proficient experts each of whom must have the ability to communicate to other members of the team and to compromise. Also, the task of integration is always formidable because each relevant knowledge base defines sub-problems of the larger whole, and a holistic approach is difficult to achieve and maintain because the recreation system being evaluated is always a part of a larger system. Data are never equally or sufficiently available on any of the parts. These problems of achieving integrated planning and management are not unique to recreation, and exist in every field of environmental planning.

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[7] Some confusion has existed in the past by use of the words "Behavioral Approach." A disclaimer might help. A strict "behavioristic," or stimulus-response, approach is not being advocated or taken. Instead, the intent is to focus more attention on the social-behavioral aspects of user demand, on-site engagement, satisfaction and benefit. Explicitly, recreation is defined as a particular type of human experience that finds its source in intrinsically (or self) rewarding voluntary engagements (mental or physical) during non-obligated time. These experiences result from participating in an activity, so that participation (or observable behavior) is instrumental (or is a "tool") for realizing the experiences--the desires for which prompted the behavior in the first place. For an elaboration see Driver and Tocher, 1974.

In sum, behavioral information is only one type that needs to be considered by planners and managers. The following section explains some of the characteristics of that type of information, especially that dealing with recreation experiences and benefits.

CONCEPTUALIZATION OF RECREATION EXPERIENCES AND BENEFITS[8]

In this section a simple and integrated model of recreation behavior is described to help structure thinking about the relation between recreationists, their aspirations, the opportunities provided and the social-benefits of these recreation services. The model described is a general one of human behavior in which many different perspectives within the social-behavioral sciences can fit. Heavy reliance is placed on the idea that man is a complex information processing and problem solving organism because that orientation makes explicit (1) the goal-directed nature, or purposefulness, of recreation behavior and (2) the need to look beyond on-site activity in evaluations of recreation demand and behavior.

Many authors have proposed directly or indirectly that most human behavior is problem solving behavior (Marshall 1890, Luce and Raiffa 1957, Festinger 1958, White 1959, Miller, Galanter and Pribram 1960, Howand and Scott 1965). In this approach a problem is not defined as a negative-adversive state but simply as a gap between an existing (or perceived probable) state and one that is more preferred. Therefore, any life situation may be defined as a problem posed to an individual according to this "relative preference" criterion. A person would have a "problem" if he were in a state of bliss and preferred more bliss; he is experiencing a gap. The problem is solved as the gap is closed.[9]

By definition then, recreation behavior is engaged in to help people solve problems (or reach preferred states) which they find better solved in recreational pursuits or they cannot solve in their non-recreational times or environments.[10] Identifying those particular preferred states which people desire to realize while recreating is one way of defining the types and relative importance of the experiences desired (or demanded) from recreation opportunities and at least inferentially of identifying the social-individual benefits gained. To illustrate, assume that a potential recreationist is experiencing a problem which causes him to desire a specific type of gratification during leisure time. The recreationist's problem, within the constraints that govern his behavior, is one of finding a recreational opportunity which will provide that gratifying experience.

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[8] This section draws heavily on a recent paper that was written on the social-psychological determinants of recreation demand (Driver and Brown 1975). The conceptual model presented is described in considerably more detail in that paper.

[9] Some problem states do not "mobilize" problem solving behavior because they are relatively unimportant and are maintained rather than solved. Others cannot be solved because of constraints, including the constraint imposed by not knowing clearly what the problem is.

[10] An earlier paper (Knopf et al. 1973) defined recreation behavior as a means of helping the users realize their "unmet needs" that could not, or for some reason, were not met in non-recreational times or spaces. The view offered here is the same if one accepts the idea that needs are defined as preferences under the philosophical suggestion that humans have no needs, only strong preferences, such as to stay alive.

Using this "conceptual framework," certain questions about recreation-related desires, experiences, and benefits become more explicit. Do the problem states that prompt a choice of wilderness camping differ from those that prompt using state parks? If so, how and why? Or, how do the recreation-related problem states of low-income residents of inner cities differ from those of affluent suburbanites, and are these problems really being solved through present recreational engagements or should they be? Specifically, are the available recreation opportunities being used primarily as a means of temporarily escaping problems that reappear when the recreationist goes back home? If so, are we dealing more with symptoms than causes? Also, how can managers as problem solvers better help the recreationist solve his recreation-related "problems?" The model illustrated in Figure 1 can help guide investigations directed toward questions such as these.

Basically, Figure 1 attempts to illustrate simply how the factors influencing or defining recreation behavior can be grouped into quantifiable sets. The nature of the model should become clearer as a hypothetical recreationist is walked through it rather quickly. The many feedback loops and the dynamic, ongoing effect of current environmental influences are omitted for purposes of simplicity.

The model proposes that a potential recreationist (B-1) has several quantifiable characteristics (such as B-1A to B-1C) each of which can help cause a particular problem state and its associated preferences to become dominant (B-2) at a particular time. To satisfy these preferences (i.e., resolve the problem), the individual considers his options (constraints and possibilities) and their expected-probable consequences (B-3). Through this decision process, he decides at some level (psychological or physiological) to (1) commit his subsequent behavior to recreational activity, or (2) engage in some other type of behavior (i.e., exit the recreation behavioral sequence)[11/]. If subsequent behavior is committed to recreational activity, the individual

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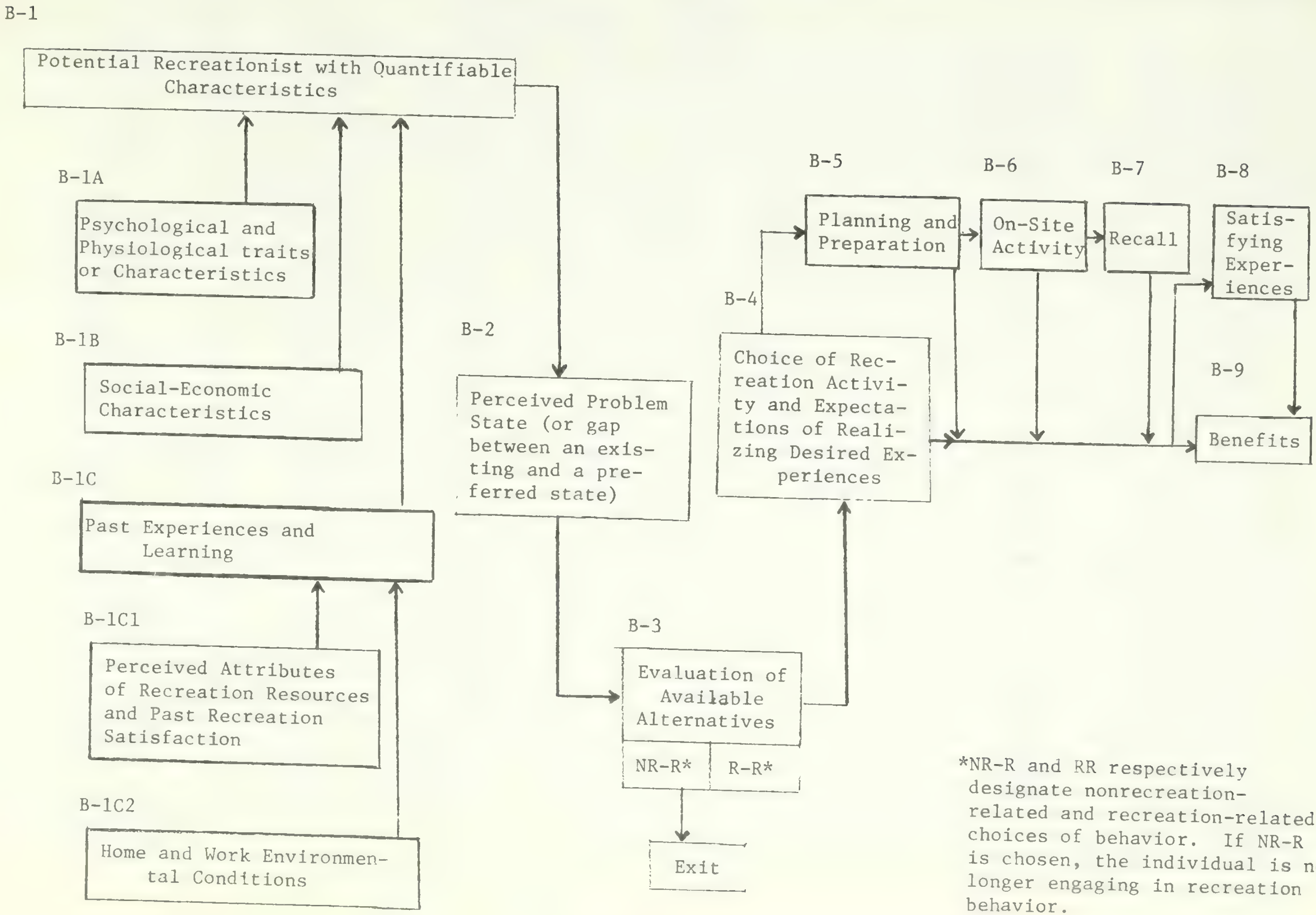
[11/] Alternately, it can be explained that the recreationist is appraising the expected utility to him of various available options in an attempt to realize a satisfactory (and not necessarily optimal) solution to his problem to the extent he is aware of the problem. That "awareness" might not be very conscious and could even be physiological and still prompt the behavior indicated. Space does not permit an elaboration of this decision-making process. It should be pointed out though that no claim is being made for a perfectly rational "economic man" who always acts in his best interest. All that is being suggested is that the decision is a purposeful one, whether or not the desired consequences are really in the best interest of the recreationist.


B-1
Potential Recreationist with Quantifiable Characteristics
B-1A
Psychological and Physiological traits or Characteristics
B-1B
Social-Economic Characteristics
B-1C
Past Experiences and Learning
B-1C1
Perceived Attributes of Recreation Resources and Past Recreation Satisfaction
B-1C2
Home and Work Environmental Conditions
B-2
Perceived Problem State (or gap between an existing and a preferred state)
B-3
Evaluation of Available Alternatives
NR-R*
R-R*
Exit
B-4
Choice of Recreation Activity and Expectations of Realizing Desired Experiences
B-5
Planning and Preparation
B-6
On-Site Activity
B-7
Recall
B-8
Satisfying Experiences
B-9
Benefits

*NR-R and RR respectively designate nonrecreation-related and recreation-related choices of behavior. If NR-R is chosen, the individual is no longer engaging in recreation behavior.

has purposefully chosen a specific recreation activity or environment[12], and this choice is accompanied by expectations of realizing desired consequences (or satisfying experiences) which are viewed as attainable (B-4). Further commitments of behavior are made to planning (B-5), traveling to the site or facility, on-site engagement (B-6, which could be a mental "site" and engagement only, say in fantasy), traveling home, and recall (B-7). From each of these behaviors (B-5 to B-7), the recreationist can realize satisfying experiences (B-8) and personal benefits (B-9)[13]. The benefits can be gained without conscious awareness, such as better muscle tone from walking an interpreted nature trail to learn.

To summarize, Figure 1 simplifies recreation behavior in an attempt to chart sequences of behavior so we can identify specific sets of variables and decision points. The model is founded in the assumption that recreation behavior is not random but instead has causes and direction even though: (1) the recreationist need not be consciously aware of these causes and preferences; (2) the behavior can be exploratory or trial and error (heuristic) as well as habitual or engrained in learning from similar past recreation experiences, and (3) the recreationist need not attempt to maximize his expected returns as would the classical economic man. Within the model, recreation satisfaction or pleasure is a feeling that finds its source in a variety of specific recreation experiences, some of which will be more satisfying than others. Furthermore, the model incorporates the idea that recreation activities are selected to realize a variety of experiences simultaneously, but that specific activities are selected by particular recreationists, within the bounds of their constraints, to realize those experiences that are of highest relative importance at any particular time. Therefore, explicit to the model is the idea that an activity will attract users who expect satisfying experiences that are relatively unique to that activity.[14] For example, the more satisfying aspects (experiences) of hunting differ from those associated with visiting an historic ruin . The challenge is to define which types of experiences are expected by which types of users, which activities best provide opportunities for specific types of experiences and which benefits are realized from these experiences.[15]

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[12] Although purposeful, the decision might be an exploratory one involving heuristic (trial and error or searching behavior) rather than more habitual-predictable behavior. Also, the decision might be quite spontaneous, or spur of the moment, although most outdoor recreation decisions would appear to involve more planning.

[13] A recent publication by the US Office of Management and Budget (Executive Office of the President, 1973) suggests that social planning should be evaluated by criteria (or social indicators) that "measure end products of, rather than inputs into, social systems." Boxes 8 and 9 of Figure 1 specify the end products of recreation "systems."

[14] Opportunities to realize these specific satisfying experiences are dependent on specific attributes of the resources, the facilities, the equipment, the users' peers and other users engaging in a particular activity. These attributes serve to facilitate (scenic mountains, big fish, few people) or to constrain (polluted streams, little fish, crowds of people) the realization of those expected and desired consequences (or pleasurable experiences) that give satisfaction. Since various recreationists perceive and value these attributes differently, they will engage in different activities.

The model suggests a three-step procedure for identifying and quantifying the personal-social benefits of recreational engagements as follows:

1. First, identify and measure the relative importance of the desired and expected consequences (i.e., expected satisfying experiences) of different types of recreationists (characterized by the various descriptors inherent in B-1A to B-1C of Figure 1) who are engaging in specific recreation activities.

2. Second, assume that the desired and expected consequences of large groups of recreationists (most of whom have participated in similar activities in the past) are reasonably well related to the personal and social benefits "sought." Then form hypotheses about the personal-social benefits derived by clearly defined types of users who rate particular activities high in importance for providing certain types of experiences. For example, it could be hypothesized that a specifically defined user group who places high importance on a certain type of fishing for purposes of "skill development" (an expected desired consequence or desired experience) realize greater self-confidence (a possible mental health benefit).

3. Test the hypotheses under experimental-controlled conditions, including the evaluation of benefits over time.

The question then arises: Can this procedure be followed and give reliable and accurate results? My answer is yes, it can to a very useful degree.

IMPLEMENTING THE PROPOSED APPROACH AND SOME METHODOLOGICAL ISSUES

For the purposes of this paper, it seems inappropriate to go into a detailed dissertation on the research procedures for, and methodological problems of, measuring social benefits. Instead a more general overview will consider these four issues: (1) how well can the expected and desired experiences and benefits be identified and measured; (2) which experiences and benefits are worth measuring; (3) what are the possible effects of researcher biases; and (4) which alternative methodologies are most suitable or appropriate?

How Well Can the Expected Experiences and Benefits Be Measured?:

Early work by Lewin (1951) and recent work in motivation psychology (McClelland et al. 1953, Birch and Veroff 1966, Atkinson and Birch 1972), and works of other social psychologists (Jones et al. 1972) indicate that we do most things for a reason and these reasons are influenced by our personalities, our values (and those of our associates), and the resources (or options) available to us, including information and our perceptions of our skills and abilities. In the language of a motivation psychologist, the relative strength of a particular "behavioral tendency" and the "motivational determinants" of that tendency can be identified and measured. The current work of Fishbein and Ajzen (1974 and 1975) suggests that specific intended or planned behaviors are closely related to subsequent actual behaviors to the extent that specific consequences of the intended behaviors are known, expected, and valued. Put more simply, subjective appraisals (attitudes, opinions, expectations, etc.) and actual behaviors are in relatively close agreement when these subjective appraisals are realistic with respect to the specific consequences that are most likely to result from specific behaviors. Much poorer relationships exist when there is little knowledge on probable consequences and when the possible consequences are of little importance. This theory is relevant to recreation then if the probable consequences of a specific recreation activity are known, expected, and valued by recreationists who intend to engage in that activity.

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[15] Activities providing similar "packages" of experiences and which are equivalent in costs (dollar, time, etc.) are probably substitutes for each other.

Most recreation opportunities are not used by recreationists who are participating for the first time, so these users have knowledge of the consequences from past participation. And many first-time participants have heard of the likely consequences from friends. Therefore, most of the people for whom public and private sector recreation demand and benefit analyses are most relevant probably have reasonably accurate ideas about the likely consequences of their recreation choices.[16/] These expected consequences are obviously valued as desirable, else the activity would not have been chosen. And if interviewing is done on-site, intended behaviors are manifested by the actual participation. The problem then becomes one of measuring the expected and desired consequences.

I believe the most pervasive and managerially relevant expectations can be measured reasonably accurately for any large group of users with similar characteristics (such as day users picnicking at a particular site during a particular time who are similar in age, income, size of home city, past picnicking experience, etc.) The desired and expected consequences of recreationists not having the benefit of past experience (i.e., not having the same predictability of probable consequences) can be measured less well. Also, the postulated close relationship between expected and actual experiences cannot be assumed as readily for this group even though information on likely consequences is frequently passed from a past to a potential participant. It is more difficult, therefore, to measure the latent or unrevealed demands of non-users. Figure 1 does, however, help define more clearly what the concept of latent demand is.[17/]

[16/] This is not to say that all expectations are met. It would seem, however, that most expectations of users that stay in the "market" are met.

[17/] The reader should be leary of results that question non-users of their expectations. It might be instructive though to infer what the demands of clearly defined types of non-users are by comparing them with users having characteristics similar to the non-users. Or useful baseline data might be obtained from research designs which appraise the degree of match between "latent" expectations and actual experiences of control groups of non-users who are provided a "real" opportunity as part of the research design.

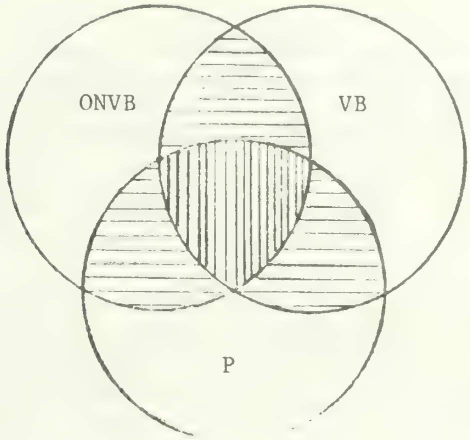
In sum, I believe the pervasive expected and desired consequences of clearly defined types of user groups can be quantified to a useful degree given the state of the art of applying behavioral science to recreation management. The following section gives an overview of the different approaches for making these measurements.

Which Research Approach Should Be Used?:

It was stated above that the demand for most types of recreation opportunities is by people who have relatively good knowledge (much of it is experiential) about the types of satisfying experiences realized from engaging in specific activities. Methodologically, the major problem is one of bringing this information to a level of consciousness or awareness at which it can be evaluated systematically so that reasonable inferences and hypotheses can be made about the personal-social benefits associated with these experiences.

At this point, many social-behavioral scientists "part company," and others look on with skepticism, because of different philosophies about the degree to which the expected and desired experiences and benefits can be identified and measured reliably and validly. It is my contention that through the application of different techniques as checks one on the other, user expectations, experiences and benefits can be identified and measured reasonably well (Kerlinger 1964, and Nunnally 1967).[18]

To elaborate, the techniques of measuring human behavior can be grouped into three categories which also define three types of behavior. These are expressed in Venn diagrams in Figure 2. The crosshatched areas represent those behavioral responses that are common across two or all three of the alternative types of measurement. These overlapping responses are probably more reliable and accurate indicators of "real" behavior than are responses that do not cross-check. For example, verbal responses might be distorted because a person being researched might be afraid to give a truthful answer, might say something that he thinks the researcher wants to hear, or might wish to bias the research results in a way favorable to his interests.



Legend

VB = Verbal Behavior
ONVB = Overt Nonverbal Behavior
P = Physiological Response

Figure 2: Three types of Human Behavior-Responses.

Questionnaires can be used to measure verbal responses (such as pencil and paper psychological tests of whether a person is an introvert or an extrovert). Unobtrusive methods can be used to examine overt nonverbal behavior (such as observing whether or not the person actually behaves as if he is an extrovert or an introvert). And mechanical-electrical instruments can be used to measure physiological response (such as determining arousal levels and causes, which seem to predict tendencies toward introversion or extroversion under specific conditions).

It is hazardous to rely on only one approach. The trick is to get cross-checking methodologies to converge (or overlap in Figure 2) in support of a particular hypothesis about a specific expected consequence, actual experience or benefit (Campbell and Fiske 1970). For example, it seems possible to measure benefits of a tranquil natural environment (feelings of reduced tension, lower observed levels of interpersonal aggressiveness; and lower blood pressure, pulse rate, etc.) using all three approaches as cross checks. Also, different procedures (such as those using physiological measures) should be used within any one approach (or circle in Figure 2) as cross checks.

In sum, human behavior is complex, but techniques do exist for measuring recreation-related expectations, experiences and benefits.[19/]

Deciding Which Expectations Are Worth Measuring:

It is known that humans have a wide variety of motivations and experiences (Murray 1938, Laing 1967). There is also a wide variety of recreation-related experiences. The problem is one of deciding which expected and desired experiences should be "pursued" in research concerned with identifying and measuring the social benefits associated with these experiences.

Researchers and managers must work together to resolve this problem. Also, further identification and classification of user expectations must be accomplished before decisions can be made regarding which consequences are most managerially relevant. Criteria will need to be established to guide this decision. Some possible guidelines are offered to illustrate the type of thinking required:

1. The expected and desired consequences or experiences should be managerially relevant or something that managers can influence either directly or indirectly. Alternatively, this criterion can be stated in terms of which types of experiences different types of managers can influence the most.
2. The expected consequences should be desired by a significant number of users (both actual and potential) and not be common to only a

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[18/] If nothing else, and I believe there will be considerably more, we will have enhanced our judgments in the process. Sometimes, asking the right question puts us considerably over halfway toward finding a satisfactory or better answer even with knowledge constraints. Also, it seems apparent that there are never ultimate and final truths (only partial and temporary answers that change as the social and other contexts change) in any field of inquiry.

[19/] For purposes of simplicity, the words expectations and desires are being used synonymously in this paper although technical arguments (which get complex) can be made that the two differ.

small percentage of the (on-site or off-site appreciative) users of a particular opportunity.

3. The expectations should relate to the administrative jurisdiction or statutory responsibilities of the public agency providing the opportunities if publicly provided.

4. Related to No. 3 above, the expectations should to some reasonable degree be related to or dependent on the resources under the jurisdiction of the supplying agency.

5. The desired experiences should be socially acceptable to a reasonable degree if the opportunities are being provided primarily by public funds.

In sum, the process of deciding what expected consequences or desired experiences and benefits should be researched is one that requires judgment. But as cited below, past outdoor recreation research indicates that certain types of desired experiences are pervasive in importance and are managerially relevant. These include: developing skills; competing or achieving; learning; being creative; exploring; being with friends, the family or like-minded associates; experiencing nature; exercising; taking risks; seeking thrills or stimulation of various types; manipulating machines; seeking privacy-solitude; reflecting-introspecting; and coping with a wide variety of adversive stimuli experienced in home, neighborhood, and work environments.

Problems of Research Bias:

In deciding which desired experiences to research, an ever present methodological question is: How is it known with assurance that the experiences and benefits identified and measured are those most important to the recreationists and not those of importance to the researcher?

Most existing research on recreation behavior reflects strongly the personalities and other personal inclinations of the researchers. This is not necessarily bad, so long as these influences do not also guide the data beyond the limits of the research designs in which they were collected. The likely deficiency is that not enough personal inclinations of recreation researchers are available to represent those of the public! In any event the researcher must be aware of the possibility of mapping his or her values onto those of the people studied. He also should be aware of the different procedures that can be used to cross-check the results of one approach with those from another, and he must work closely with managers.

STATE OF THE ART OF THE DESCRIBED APPROACH

Considerable descriptive research has been directed at determining relationships between recreation participation and socio-economic variables (B-1B, in Figure 1), such as income and occupation. However, most of the behaviorally oriented outdoor recreation research has been attitudinal in nature and has relied on questionnaires designed to solicit subjective responses to conditions specified by the researcher. A few studies have been reported using direct observation techniques to measure overt non-verbal behavior.

Most of the behavioral research has also been applied or strongly managerially oriented rather than basic or developmental. As such, it has not contributed greatly toward the development of a body of knowledge (Driver and Knopf 1975a). Despite these problems, results from past recreation research support the approach proposed in this paper for identifying and measuring benefits. A few representatives of these empirical studies, which are directly relevant to the behavioral scheme offered in Figure 1, will be mentioned.

Empirical research directed specifically at the antecedents of recreation choice and activity support the idea of problem solving during recreation behavior as proposed in this paper. Examples include reports by Catton (1969), Burch (1969), Ferris (1970), Meyersohn (1970), Witt and Bishop (1970), Knopp (1972), Mandell and Marans (1972), Morris et al. (1972), Sofranko and Nolan (1972), Davis (1973), Grubb (1975), Kelly (1974), LaPage and Ragain (1974), Driver and Knopf (1975b), and Foss (1975).

Other studies focusing on specific types of problems indicate a strong influence of home, neighborhood, and work environments on choice of recreation activity, reasons for that choice and amount of participation. For example, Grubb (1975) found relationships between auto workers' perceptions of job boredom, choice of activity, types of experiences sought, and days of participation in those activities which were viewed as more stimulating that the workers' jobs. Several studies (Mandell and Marans 1972, LaPage and Ragain 1974, Driver and Knopf 1975b) found that the relative importance of various types of desired and expected experiences differ for users characterized by different socio-economic variables such as age, sex, income, city size, stage in family-life cycle, perceived quality of home and work environments and other variables. Bassett et al. (1972) found that users of Michigan's AuSable River who differed in their expected consequences also differed in their perceptions of the severity of the conflicts between canoeists and trout fishermen. These differences were especially pronounced between the users who did, and those who did not, desire to see and be with other people on the river.

Knopf (1972) did a rather comprehensive review of the research, through 1971, addressed to relationships between recreation activity and changes in personal-individual traits such as self-esteem, dominance, etc. He also reviewed thoroughly the research literature dealing with the motivational bases of outdoor recreation choice and with the users' perceptions of satisfaction received. The research reviewed and reported since 1971 (e.g., Knopf et al. 1973, More 1973, Potter et al. 1973, Hendee 1974, Peterson 1974a, 1974b, Brown and Hautaluoma 1975, and Orthner 1975) indicate pervasive themes about expected consequences or experiences sought. Some example results from research with which I have been associated will be presented for illustrative purposes.

Tables 1 and 2 show some of the expected consequences sought by the different test groups of recreationists indicated. Sample sizes are small because the purpose of the research was to develop instruments to measure the consequences by using test groups of users rather than to apply the instruments to representative samples of users. The methodology is explained in detail elsewhere (Knopf 1972). Briefly, the procedure consists of asking recreationists to check in a questionnaire how important each of a long list of reasons (i.e., expected consequences) were to them when they decided to engage in the activity

TABLE 1.--Mean scores of 10 different test groups of Michigan recreationists to selected expected consequences scales.[a/]

Expected consequences	Trail biking	Pic-nick-ing	Social camp-ing	Back country camping	Back country hiking	Trout fish-ing	Warm water fish.	Sail boat-ing	Tennis	Golf
Achievement	5.7	3.0	4.4	3.9	4.9	4.7	4.6	5.7	6.7	5.5
Avoid others' expectations	5.4	5.5	6.0	5.6	5.0	4.9	5.7	4.4	4.3	4.3
Being with others	6.2	5.9	7.0	4.6	5.2	4.0	5.4	5.4	5.7	5.5
Dominance-control	4.1	2.2	3.0	2.7	3.5	2.5	3.1	3.5	3.5	3.4
Exercise-phys. fitness	4.1	4.1	4.5	3.8	5.6	3.6	3.5	4.2	7.3	4.9
Experience nature	5.8	7.0	7.5	7.8	7.6	7.3	6.8	6.2	2.7	5.0
Exploration	6.1	5.2	6.2	5.7	6.7	5.0	5.8	5.7	3.5	3.7
Family togetherness	4.4	5.9	7.4	5.7	4.6	4.0	5.3	4.4	3.5	4.1
General escape	5.9	6.5	6.6	6.4	5.6	6.2	6.0	5.6	4.3	4.7
Mental change	5.4	6.3	6.4	5.4	5.4	5.7	6.0	5.2	5.1	5.2
Social recognition	3.5	2.2	3.2	2.5	3.4	3.3	2.3	3.2	3.6	3.3
Tension release	5.0	5.4	5.4	4.1	4.2	3.9	4.8	4.6	5.8	4.9
Risk-taking	4.3	2.3	2.9	2.4	3.4	2.6	2.9	3.5	2.3	2.9
Sample size	51	56	52	49	47	25	30	49	51	46

[a/] Responses were to a 9-point scale format on which Extremely Important was coded 9 and Not At All Important was coded 1.

Table 2.--Ranking of test groups of Colorado snowmobilers' and cross country skiers'expected consequences.

X-C Skiers' expected consequences ranked by importance (N=71)	Mean score[a]	Snowmobilers' expected consequences ranked by importance (N=22)	Mean score[a]
1. Experience nature	4.9	1. Experience nature	4.3
2. Exercise	4.9	2. Family togetherness	4.0
3. Exploration	3.8	3. Being with friends	3.7
4. Being with friends	3.8	4. Exercise	3.5
5. Change-variety	3.6	5. Change-variety	3.5
6. Achievement	3.3	6. Exploration	3.2
7. Mental disengagement	3.2	7. Being with other people	2.9
8. Tension release	3.0	8. Mental disengagement	2.5
9. Independence-autonomy	2.9	9. Tension release	2.3
10. Being with other people	2.4	10. Achievement	2.2
11. Arousal seeking	2.4	11. Arousal seeking	2.2
12. Family togetherness	2.4	12. Independence-autonomy	2.1
13. Dominance-control	2.3	13. Dominance-control	1.3

[a] Responses were to a 6-point scale format on which Extremely Important was coded 6 and Not At All Important was coded 1.

in which they were participating when interviewed.[20] These reasons were grouped into "Expected Consequences Scales" (shown in the tables) by statistically combining similar reasons. For example, "to exercise," "to keep physically fit," "to improve my physical health" and other similar expected consequences were combined into an Exercise-Physical Fitness Scale. By computing mean responses for each scale, the average importance given to the expected and desired consequences making up that scale could be determined for each recreationist, and thereby an overall mean response could be computed for each type of activity.

Table 1 shows how 10 different test groups of Michigan recreationists varied in the importance they assigned each of 13 different types of expected consequences when they were deciding to engage in the activities shown. It can be noticed that exercising and achievement (skill development) were of the most importance to the 51 tennis players interviewed. Experiencing nature was least important to that group of users but was quite important to the test groups of back country campers and hikers. Other comparisons, such as the trail bikers' desire to take risks, will be left to the reader. The table does indicate that any one activity provides a variety of (and not just one type of) satisfying experiences and also that some of these experiences are more important or satisfying than others for a particular activity.

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[20] Responses could range from Extremely Important to Not At All Important.

Table 2 shows similar results for test groups of Colorado snowmobilers and cross-country skiers. That table ranks the relative importance of the expected consequences for both types of user. It is interesting to notice the similarities and differences in their preferences or expectations.

Tables 1 and 2 are examples of the types of results obtainable from the proposed approach. Some of the other studies showing similar findings were referenced above. All of these results help confirm the propositions (1) that specific types of activities are engaged in to realize the satisfying experiences that are relatively unique to that activity, and (2) that many of the experiences are highly dependent on the values inherent in specific resources required for a particular activity. These resources include game animals, tranquil settings, group accommodations, and cultural-historic restorations.

Admittedly, human behavior is complex and the problems of uncontrolled or intervening variables pose difficult problems for research. Nevertheless, progress is being made in structuring behavioral problems in managerial terms and in getting managerially useful results. Much more certainly needs to be done so that the actual and potential users' preferences, actual experiences and benefits can be identified to help assure that recreation resources are allocated to their highest purposes.

NEEDS FOR FUTURE RESEARCH AND SOME PROBLEMS OF IMPLEMENTING THE RESULTS

Since this paper has been a call for more research on the social benefits of outdoor recreation, few additional comments will be made on research needs. To iterate, however: research is needed to define and quantify the expected and desired consequences or experiences sought and the short-term and long-term benefits gained by different types of users who participate in specific types of outdoor recreation activities; the relationships between these benefits and conditions experienced back home need to be investigated more thoroughly; and research designs should employ techniques using subjective-verbal, unobtrusive-observational, and physiological measures.

The need for this type of behavioral research have been recognized in several national evaluations. One of the four chapters in the 1969 National Academy of Sciences' evaluation of outdoor recreation research was addressed to these needs and was entitled "The Social and Behavioral Dimensions of Outdoor Recreation" (NAS, 1969). The 43 managers and researchers at the September 1974 National Outdoor Recreation Research Needs Workshop ranked "Social and Behavioral" studies as an area of high research priority (BOR, 1975). Similarly, the recent publication by the National Academy of Sciences entitled "Assessing the Demand for Outdoor Recreation" called for more behavioral information in recreation demand analyses (NAS, 1975). The point is that the need for this type of information is recognized nationally. However, resources necessary to conduct adequately this type of research need yet to be mobilized. These resources include not only monetary support but also the support and endorsement of recreation agency administrators. Even if these resources were mobilized, however, the results would not be easy to implement or apply for several reasons.

Although a growing number of managers realize the need for a better understanding of recreation behavior, some of them experience understandable difficulty in relating to that body of knowledge and its applications to management for several reasons. First, many recreation resource planners and managers are not familiar or comfortable with the social-behavioral sciences because most of their training has been in the natural-physical sciences. In fact, many professionals trained in the natural-physical sciences view the social sciences with a certain degree of suspect, part of which is justified. Second, a behavioral interpretation of recreation broadens considerably the scope of many managerial problems, makes explicit certain questions that do not have clearcut answers, and/or the answers are frustrating because they suggest solutions that are not under the discretion-jurisdiction of the manager. Third, human behavior is complex, and behavioral information requires acquiring a new vocabulary or at least gaining an understanding of new concepts and research approaches. Fourth, many of the managerial applications indicated by the research (such as off-site education of users and concern about latent demands) require unusual time and other resources of managers who are operating under everyday constraints and pressures of an immediate nature.

Although there are difficulties, I am optimistic that recreation managers and researchers will be working more closely together in the future to accomplish our mutual objectives. All indications point in that direction.

SUMMARY

This paper has proposed that much additional research on the personal-social benefits of participation in outdoor recreation is needed to take us beyond our current intuitive understandings of these benefits. A model was presented to help show the linkages between user expectations, experiences and benefits. Within that model, the outputs or products of recreation management systems were defined not only as opportunities but also as human experiences and benefits the latter two are the real goods and services produced.

The basic premise on which the conceptual framework of the paper rested was that the most pervasive and managerially relevant satisfying experiences and personal benefits realized from recreation behavior can be identified and measured to a managerially useful degree.

One must acknowledge seriously that there are risks involved of over-rationalizing the field of recreation behavior in attempts to identify users' expectations, experiences and benefits. The subject might be so complex that these variables are, in fact, not measurable, and that we are deluding ourselves to propose otherwise. We must be careful not to "use the users," misrepresent them, or adopt research and management strategies that do not account for all relevant preferences. Real options for choice must be preserved or created to the extent feasible,and the user's self-respect must be protected. To do that, the user must be kept aware that his preferences are being evaluated, and the purposes for doing so must be explained. Also, as a "cross-check" on the researchers and managers, users should be involved in the allocation decision process. Thereby, the use of behavioral information in planning and management decisions can be reviewed by the publics for whom these decisions are made.

Despite these risks of implementing the proposed approach, the risks of not doing so are equally great and might be quite costly socially. The field is too important socially to continue to rely primarily on intuition to guide most of our recreation management and policy decisions. In the face of increased relative scarcity of our natural resources and with the growing problems associated with urbanization, better measures are needed of what should be produced, for whom, by whom, where, when and at what price. But it will take time and the strong support of managers and administrators.

LITERATURE CITED

Ajzen, I. and Fishbein, M. 1975. Attitudinal and normative variables as predictions of specific behavior. J. of Personality and Soc. Psych 27(1): 41-57.

Atkinson, J. W., and Birch. D. 1972. Motivation: The dynamics of action. New York: Wiley.

Bassett, J. R., Driver, B. L., and Schreyer, R. M. 1972. User study: Characteristics and attitudes, Michigan's Au Sable River. Rogers City, Mich.: Northeast Mich. Reg. Plann. and Dev. Comm.

Berlyne, D. E. 1960. Conflict, arousal and curiosity. N.Y.: McGraw Hill.

Berlyne, D. E. 1969. Laughter, humor and play. _In_ G. Lindzey and E. Aronsan (eds.) The handbook of social psychology. 2d ed. 3:795-852. Reading, Mass.: Addison Wesley.

Birch, D. and Veroff, J. 1966. Motivation: A study of action. Brooks-Cole, Belmont, Calif.

Brown, P. J., Dyer, A., and Whaley, R. S. 1973. Recreation research--so what? J. of Leisure Res. 5(1):16-24.

Brown, P. J., and Hautaluoma, J. 1975. Social inputs to setting deer hunting management objectives. Paper presented at the Sixth Annual Meeting of Environmental Design Research Assoc., Lawrence, Kansas.

Burch, Jr., W. R. 1965. The play world of camping: Research into the social meaning of outdoor recreation. Am. J. of Sociol. LXX(5):7604-12.

Burch, Jr., W. R. 1969. The social circles of leisure: Competing explanations. J. of Leisure Res. 1(2):125-48.

Bureau of Outdoor Recreation. 1974. Proc. of the Outdoor Recreation Research Needs Workshop. Harper Ferry, W. Va.: US Dep. of Interior.

Campbell, D. T., and Fiske, D. W. 1970. Convergent and discriminant validation by the multitrait-multimethod matrix. _In_ G. F. Summers (ed.) Attitude measurement, p. 100-122. Chicago: Rand McNally and Co.

Catton, Jr., W. R. 1969. Motivations of wilderness users. Pulp and Paper Magazine of Canada (Woodlands Section), Dec. 19, p. 121-26.

Clark, R. N., Hendee, J. C., and Campbell, Frederick L. 1971. Values, behavior, and conflict in modern camping culture. J. of Leisure Res. 3(3): 143-59.

Clawson, M., and Knetsch, J. 1966. Economics of outdoor recreation. Baltimore: Johns Hopkins Press.

Davis, R. L. 1973. Selected motivational determinants of recreational use of Belle Isle Park in Detroit. Unpub. master's thesis, School of Nat. Resour., The Univ. of Michigan.

Driver, B. L. 1972. Potential contributions of psychology to recreation resource management. In J. Wohlwill and D. H. Carson (eds.) Environment and the social sciences: Perspectives and applications, pp. 233-244. Wash., D.C.: American Psychological Association.

Driver, B. L., and Brown, P. J. 1975. A social-psychological definition of recreation demand, with implications for recreation resource planning. Commissioned paper as Appendix A in Assessing demand for outdoor recreation. Wash., D.C.: National Academy of Science.

Driver, B. L., and R. C. Knopf. 1975a. Some thoughts on the quality of outdoor recreation and other constraints on its application. Paper presented at Workshop for outdoor recreation researchers and cooperators, Brandon Springs, Tennessee (March 10, 1975). Proceedings available from K. Chilman, For. Dept., Southern Illinois University.

Driver, B. L., and R. C. Knopf. 1975b. Relationships between recreation behavior and environmental stress. Forthcoming in Environment and Behavior.

Driver, B. L., and Tocher, S. R. 1974. Toward a behavioral interpretation of recreation, with implications for planning. pp. 9-31. In B. L. Driver (ed.) Elements of outdoor recreation planning. Ann Arbor: The Univ. of Michigan Press.

Executive Office of the President, Office of Management and Budget. 1973. Social indicators, 1973. Wash., D.C.: Gov. Printing Office.

Ferris, A. L. 1970. The social and personality correlates of outdoor recreation. In S. Z. Klausner (ed.) Society and its physical environment. Annals of American Academy of Political and Social Sciences, 389:46-55.

Festinger, L. 1958. The motivating effects of cognitive dissonance. In G. Lindsley (ed.), Assessment of human motives. N.Y.: Grove Press.

Fishbein, M., and Ajzen, I. 1974. Attitudes towards objects as predictors of single and multiple behavioral criteria. Psychological Review, 81(1): 59-74.

Foss, M. 1975. Physiological benefits of chronic exercise. Paper presented at the Sixth Annual Meeting of Enviornmental Design Research Assoc., Lawrence, Kansas.

Freud, S. 1955. Beyond the pleasure principle. In J. Strachey (ed. and trans.) The standard edition of the complete psychological works of S. Freud, 1920-22. Vol. 18. London: Hogarth and the Institute of Psychoanalysis.

Grubb, E. A. 1975. Assembly line bordom and individual differences in recreation participation. J. of Leisure Res. 7(4):256-269.

Hendee, J. C. 1971. Sociology and applied leisure research. Pacific Sociological Review, 14(3):360-68.

Hendee, J. C. 1974. A multiple-satisfaction approach to game management. Wildlife Soc. Bull. 2(3):104-13.

Hendee, J. C., and Harris, R. W. 1970. Foresters' perceptions of wilderness-user attitudes and preferences. J. of For. 759-762.

Howard, A., and Scott, R. B. 1965. A proposed framework for the analysis of stress in the human organism. Behavior. Sci. 10(2):141-60.

Jones, E. E., Kanouse, D. E., Kelley, H. H., Nisbett, R. E., Valins, S., and Weiner, B. 1972. Attribution: Perceiving the causes of behavior. Morristown, N.J.: General Learning Press.

Kelly, J. R. 1974. Socialization toward leisure. J. of Leisure Res. 5(3):181-93.

Kerlinger, F. N. 1964. Foundations of behavioral research. N.Y.: Holt, Rinehart and Winston, Inc. Chap. 26-29.

Knetsch, J. L. 1974. Assessing the demand for outdoor recreation planning. In B. L. Driver (ed.) Elements of outdoor recreation planning. pp. 131-136. Ann Arbor: The Univ. of Mich. Press.

Knopf, R. C. 1972. Motivational determinants of recreation behavior. Unpub. master's thesis, School of Nat. Resour., The Univ. of Mich., Univ. Microfilms, No. M-4244, 268.

Knopf, R. C., Driver, B. L., and Bassett, J. R. 1973. Motivations for fishing. pp. 191-204. In Transactions of the 38th North American Wildlife and Natural Resources Conference. Wash., D.C.: Wildlife Management Inst.

Knopp, T. B. 1972. Environmental determinants of recreation behavior. J. of Leisure Res. 4(2):129-38.

Laing, R. D. 1967. Politics of experience. N.Y.: Random House.

LaPage, W. F., and Ragain, D. P. 1974. Family camping trends--an eight-year panel study. J. of Leisure Res. 6(2):101-12.

Lewin, K. 1951. Field theory in social science: Selected theoretical papers. N.Y.: Harper and Row.

Lucas, R. C. 1964. Wilderness perception and use: The example of the Boundary Waters Canoe Area. Nat. Res. J. 3(1):394-411.

Luce, R. D., and Raiffa, H. 1957. Games and decisions. N.Y.: Wiley.

Mandell, L., and Marans, R. 1972. Participation in outdoor recreation: A national perspective. Institute for Social Research, Ann Arbor: The Univ. of Mich.

Marshall, A. 1890. Principles of economics. London: MacMillan.

McClelland, D. C., Atkinson, J. W., Clark, R. A., and Lowell, E. L. 1953. The achievement motive. N.Y.: Appleton-Crofts.

Meyersohn, R. 1970. The charismatic and the playful in outdoor recreation. In S. Z. Klausner (ed.) Society and its physical environment, Annals of Amer. Academy of Political and Social Sci. 389:35-45.

Miller, G. A., Galanter, E., and Pribram, K. H. 1960. Plans and the structure of behavior. N.Y.: Holt, Rinehart and Wilson.

More, T. A. 1973. Attitudes of Massachusetts Hunters. pp. 72-76. In J. C. Hendee and C. Schoenfeld (eds.) Human dimensions in wildlife programs. Seattle: People-Natural Resour. Res. Council.

Morris, G., Pasewark, R., and Schultz, J. 1972. Occupational level and participation in public recreation in a rural community. J. of Leisure Res. 4(1):25-32.

Murray, H. A. 1938. Explorations in personality. N.Y.: Oxford Univ. Press.

National Academy of Sciences. 1969. A program for outdoor recreation research. Wash., D.C.

Nunnally, J. C. 1967. Psychometric theory. Chap. 13-14. N.Y.: McGraw Hill.

Orthner, D. K. 1975. Leisure activity patterns and marital satisfaction over the marital career. pp. 91-102, J. of Marriage and The Family.

Peterson, G. L. 1971. Motivations, perceptions, satisfactions and environmental dispositions of Boundary Waters Canoe Area users and managers. Final report, cooperative research project No. 13-253 between Northwestern Univ. and the North Central Forest Experiment Station, U.S. Forest Service: Dept. of Civil Engineering, Northwestern Univ., Evanston, Illinois.

Peterson, G. L. 1974a. Evaluating the quality of the wilderness environment: Congruence between perception and aspiration. Environment and Behavior 6(2):169-93.

Peterson, G. L. 1974b. Managers and canoeists in the Boundary Waters Canoe Area. J. of Leisure Res. 6(3):194-204.

Piaget, J. 1962. Play, dreams and imitation in childhood (C. Cattegno and F. M. Hodgson, trans.). N.Y.: Norton.

Potter, D. R., Hendee, J. C., and Clark, N. N. 1973. Hunting satisfaction: Game, guns, or nature. pp. 62-71. In J. C. Hendee and C. Schoenfeld (eds.) Human dimensions in wildlife programs. Seattle: People-Natural Resour. Res. Council.

Sofranko, A. J., and Nolan, M. F. 1972. Early life experiences and adult sports participation. J. of Leisure Res. 4(1):6-18.

Twiss, R. N. 1974. Supply of outdoor recreation. pp. 137-143. In B. L. Driver (ed.) Elements of outdoor recreation. Ann Arbor: The Univ. of Mich. Press.

Wagar, J. A. 1964. The carrying capacity of wild lands for recreation. Wash., D.C.: Society of Am. For. (Monograph 7).

White, R. W. 1959. Motivation reconsidered the concept of competence. Psychology Review 66(5):297-333.

Witt, P. A., and Bishop, D. W. 1970. Situational antecedents to leisure behavior. J. of Leisure Res. 2(1):64-77.

A CRITIQUE OF THE PAPER ENTITLED "IDENTIFYING SOCIAL BENEFITS OF OUTDOOR RECREATION"

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The paper addresses a complex area--identification of personal-social benefits of outdoor recreation participation--to help understand recreation behavior. The relevance of this topic and its interweaving with a whole gamut of other recreation concerns, such as substitutability, is increasingly being recognized by recreation planners and managers.

The need to measure the attractants of various recreation opportunities is further emphasized by the recent upsurge in interest in new types of recreation and activities involving more of a challenge or degree of danger.

This paper points up the need for additional work, and certainly has merit as a beginning towards more applicable research. However, this critique is supposed to address usability from a manager's perspective. The following questions and comments are offered as those that might be raised by a manager.

Application would be greatly influenced by the constraints already imposed on managers--such as budget, existing policy, physical design of a facility, environmental restrictions, and operation and maintenance obligations. Thus, early consultation with managers should be sought in determining what recreation experiences are relevant for their use.

Use of this research in allocating recreation resources would probably be more applicable at the planning level. Usability by "managers" in this respect would be contingent upon the extent of the "manager's" authority relevant to resource allocation. However, use by managers with programmatic responsibilities would be more applicable.

Variables, or "environmental influences" as the author refers to, are many and apt to change, thereby influencing the recreationist's interest and/or gratification. Perceived benefits in the recreationist's mind may change due to the "environmental influences" and thus vary at time of interview, time of activity and when he anticipates or repeats that same activity. The author refers to this as "extinction of benefits."

Can motivation and benefits perceived by individuals at one point in time be collectively compiled and analyzed to produce findings and recommendations applicable to masses of recreationists for a projected length of time?

Driver has considered this and stated that managers and researchers must not think "truth" has been reached--the answers are only temporary and partial. If so, it is questionable that long-range planning and management decisions can be influenced by the research reviewed in this paper.

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PUBLIC INVOLVEMENT IN RECREATION RESOURCES DECISION MAKING

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Abstract.--In response to legal and administrative requirements, federal natural resource agencies are involving citizens in the decision making process. However, given the arguments stated both for and against public involvement, one might raise a question about the proper role of involvement in agency decision making. While twelve general principles of public involvement and a number of relatively new public involvement techniques, e.g., public information brochure, nominal group and Delphi, are discussed, research has not progressed to the point where "formulas" for involvement can be given. Agency cooperation is vitally needed to permit a comparative evaluation of alternative techniques.

Additional keywords: Citizen participation, public relations, public preferences, public administration, recreation planning, water resources planning, forest land planning.

INTRODUCTION

In recent years, public participation (citizen involvement) has become institutionalized in much of natural resource agency decision making. While one might question the validity of agency involvement in what is often considered the "political arena," it is in effect required. For example, the National Environmental Policy Act of 1969 (NEPA) and Executive Order 11514 mandates public involvement with respect to major actions. In addition to these requirements, agencies have also been subjected to court challenges, protests, and other activities by organized groups demanding either different decisions or inclusion in the decision making process.

To avoid conflict, to implement legislative and executive directives, and to act on recommendations of the Public Land Law Review Commission (1970) and the Conservation Foundation (1972), federal agencies such as the Forest Service, Park Service, Bureau of Land Management, and Corps of Engineers are seeking to develop improved procedures for involving citizens in the agency decision making process. Efforts to develop public involvement procedures are also occurring in various state, county, and multicounty planning jurisdictions in relation to land use planning; however, whether these procedures are being developed as a consequence of legal requirements or administrative initiative is not clear. Passage of a national land use policy act will ultimately require the development of public involvement procedures to establish land uses within and between all governmental jurisdictions.

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There are differences of opinion about the meaning of the term, "public involvement." For this paper, public involvement will be defined as any activity which brings the viewpoints of organized citizen groups or individual expressions into an agency for consideration.

There are basically two sets of activities which may generate public involvement: (1) concerted action by citizens which results in developing communications with an agency, e.g., citizen opposition to a proposed highway through a park; and (2) agency-initiated public involvement as a result of legislative mandates, agency sensitivity to the importance of an issue, or agency commitments to programs. In this paper we will discuss the latter form, that is, agency-generated public involvement programs.

There is a wide range of potential forms of public involvement in planning and decision making. At one end of the continuum is an organizational-expert system where plans and policies are formulated by using a rational decision making process (Bultena and Rogers 1973). Non-agency persons are minimally involved in this case.

At the other end is a democratic-participatory system in which the public is involved directly and continuously throughout the entire planning process rather than at the end after all plans and policies have been determined. Between "the expert" and "the participatory" system are various systems where public views are sought at various stages, and where the degree of public involvement ranges from occasional consultation to no consultation at all. For a description of various systems see Davis et al. (1975) and Bishop (1970).

For those agencies that use "the expert" system, the presumed advantage is employment of professional ethics and standards which are "value free" with respect to programs and a rational decision making process in which goals are clearly defined, pertinent data collected, the range of alternatives and their consequences specified, and the most efficient alternatives selected. However, it is recognized that, in fact: (1) these goals are often unclear, (2) the data collected is never the sole criterion used to make decisions, and (3) choices are restricted to alternatives that are known, available, and consistent with the agency's mission.

Use of "the participatory" system by agencies, on the other hand, is based on the recognition that agency decisions are considerably influenced by social and political forces from within and outside the agency. Policy is influenced by the exercise of pressure by interest groups upon agency officials and elected representatives. Decision making is seen as a very complex process which is sporadic and involves bargaining between agency officials and the public (Wengert 1955, Holden 1966, Hagevik 1970).

While NEPA requires public involvement on all major federal actions and Executive Order 11514 requires agencies to develop procedures to assure understanding of proposed actions and to solicit public views, these mandates lack sufficient specificity. For agencies with these mandates and any other agency attempting to develop public involvement procedures, there are a number of very difficult questions which must be answered. Who is "the public"? How should they be involved? On what issues should they be involved? At what point in the decision making process? For what length of time during agency decision making? One could go on and on raising questions but the most troublesome would still be how can it be done effectively, since no criterion of effectiveness exists with regard to public involvement.

PROS AND CONS

Arguments For Public Involvement

As we see it, there are four major arguments for public involvement in decision making.

1. Public involvement has recently been promoted for ethical reasons. The argument is that citizens have an inalienable right to be involved in the formulation and implementation of agency programs. These ethical considerations relate to the fact that those who are to be affected by a policy, or who are to pay for it have a right to be consulted (Sewell 1974, Morley 1974, Folkman 1973).

2. Public involvement is needed to make management decisions which reflect the wishes and needs of the citizenry. Management decisions involve both policy and technical aspects. The policy aspect concerns what ought to be, and therefore, involves a consideration of social values--which benefits are most important and what level of costs are acceptable to the public. The technical aspect concerns the possibilities for and the consequences of following alternative courses of action in achieving objectives.

Ultimately citizens must guide or at least consent to management decisions. Managers and planners should, therefore, attempt to use information on public preferences as well as technical expertise in making decisions (Wagar and Folkman 1974, Davis and Bentley 1967, Bultena et al. 1973, O'Riordan 1971a). Since many studies have demonstrated managers or planners do not know the preferences of citizens, it is particularly important that managers seek this information (e.g., Hendee and Harris 1970, Bultena and Hendee 1972).

In many cases planners and managers erroneously assume that they are aware of the social costs and benefits of a decision. Input from people to be affected by the decision would enable better estimates of social costs and benefits.

3. Public involvement would provide information on aesthetic and other environmental values that have not generally been included in benefit-cost analysis. At best, such analyses only provide an estimate of the least (rather than the most) which people would be willing to pay to maintain environmental quality (O'Riordan 1971a). For example, using public opinion polling, as a public involvement technique, researchers reached different conclusions about the benefits and costs of proposed reservoir development projects than were reached by benefit-cost analysis (Bultena and Rogers 1974).

4. Public involvement will often identify a greater range of management alternatives and obtain a wider basis of support for the implementation of management decisions. With this expanded range of alternatives, completely unacceptable choices will likely be omitted before they are implemented. In addition, by involving those persons likely to be affected with those that affect plans, it may be possible to anticipate unforeseen consequences.

If people are involved in the decision making process, they will have a better understanding of the meaning of a decision for them and thus are more likely to support the implementation of the decision. To be successful, a decision must not only be beneficial and feasible, but also acceptable to a majority of the population that is affected (Wilkinson 1974). For individuals who provide input into the decision making process, personal satisfaction and morale is increased as a result of being included in the process. It also contributes to responsible behavior (Smith 1973).

Arguments Against Public Involvement

There have been a number of major arguments raised against public involvement (Wilkinson 1974 and Bultena and Rogers 1973).

1. It encourages mobilization of antagonistic interests. It has been the experience of agencies, in some cases, that proposed programs were defeated after the agency aroused the public about an issue. Furthermore, public involvement has the potential for opening a political Pandora's Box (Wengert 1974).

2. It is costly in terms of time and money and may serve to slow down efficient decision making. Agency administrators cannot afford the time and costs of obtaining public involvement on many official actions.

3. Citizens lobby for local interests or special privileges. Lobbying can prevent the initiation of projects that have more widespread benefits. Wengert (1974:119) notes that: "Participation becomes a mockery when local objectors are permitted to frustrate decisions that affect a regional or national interest. This is not to say that local objectors should not be heard, but the sad fact is that the procedures do not prevail for recording the interest of any others."

4. In general, citizens are not involved in the decision making process. Those who are active may not be representative of the public as a whole. Many citizens remain silent because of their lack of concern, interest, knowledge, motivation or time. Any program of citizen involvement should include this "silent majority" (Wengert 1974). Though the majority may be silent, this may not mean indifference. Silence may be as much a function of political alienation and limited information as it may be to the holding of mild preferences (O'Riordan 1971b).

5. Many resource problems involve complex technical issues which may be beyond the competence of the citizen to understand.

6. Various forms of public input are difficult to weigh in making a decision. Because of the lack of clear direction from the legislative branch of government, many agencies have difficulty weighing the various forms of public input. Any scheme of public involvement, according to Wengert (1974: 124), "must face the issue of weighing the views and opinions, distinguishing between preferences and public interest."

7. Public involvement in an agency cannot avoid the dilemma of cooperation and manipulation of public support by disseminating selective or tainted information, winning support by favors, and otherwise influencing outcomes (Wengert 1974:125). Previous studies have found that agencies will, initially, only disseminate information that will show the benefits of the project with little or no information on the costs (e.g., Stamm and Bowes 1972).

8. The results of some forms of public involvement are unpredictable. The point has not been reached where one can choose a technique and be certain that it will work in all situations (Davis et al. 1975).

SOME GENERAL PRINCIPLES

There are a number of general principles that should be kept in mind when an agency is contemplating public involvement.

1. Involve the public on those issues that appear to have important consequences for society. The decision making costs of information dissemination and collection are too high to have public involvement on a large number of issues. Some decisions must be based on the manager's experience or "hunches." While there are costs for the agency, there are also costs to the citizen. It is generally known that only a limited number of persons can or will take an active part in matters that affect them. The costs of acquiring the information necessary for active involvement and the costs of negotiation are too high (Buchanan and Tullock 1962, Downs 1957). Individuals often lack sufficient interest in many of the problems to organize and select representatives to aid in decision making (Olson 1965).

Decisions to seek public involvement should be based on a sensitivity to public interests. There are a number of criteria that can be considered in making a decision about whether to seek public involvement. Among these are: (1) number of persons likely to be affected by the decision, (2) geographic size of the area to be affected, (3) value of the resource (economic, aesthetic), (4) expenditures required to implement the decision, (5) anticipated public interest in the decision, and (6) legislative mandates.

2. Decide the referent of the term "public." It is critical that the agency decide whether the program is to be aimed at the general citizenry, a segment or segments thereof, or some combination of these. This, in effect, determines the nature of the involvement effort.

3. Define the objectives of public involvement and develop performance criteria. A number of studies have indicated the importance of specifying objectives and developing performance measures (Copp 1973, Hendee et al. 1973, Middaugh 1973). More progress is apparent in the former than the latter. An outstanding example which one might cite in performance measurement is that of the Ontario Provincial Government (1974), which has developed a set of criteria for measuring program performance.

4. The objectives and procedures of involvement should be communicated to the public. It is important that the agency clearly spell out how the public involvement "game" will be played. For example, an agency should indicate who has the responsibility for the final decision and the various factors that will be taken into account in making the final decision. It should also indicate that the objective is to reach agreement on the decisions and that reaching agreement will require some bargaining by both sides. It is important to build a sense of trust and confidence so that participants will want to "play" again. Specification of the rules of the "game" should effectively minimize polarization of values and preferences.

5. Public involvement must be sought before a decision has been reached. There is general agreement in the literature that people have been involved too late in the decision making process (e.g., Hendee et al. 1973, Wilkinson 1974, Copp 1973). It has typically been the case that people have been asked to react to decisions that have already been made by an agency. There is no sense in going through the motions of asking for a response when the agency has "made up its mind"; moreover, there is no quicker way to alienate the public than to ask for comments after a decision has been made (U. S. Forest Service 1974). Earlier involvement will be more likely to establish trust and confidence in the agency.

Ideally an agency would involve the people in assessing the problem, suggesting alternative actions, assisting in describing impacts, and finally, expressing preferences on alternative actions (Ortolano 1974). While the ideal calls for involving people at all stages in the decision making process, the decision about the stages of involvement would have to be evaluated in terms of the benefits and costs to the agency and to the participants.

The "fishbowl" planning process developed by the U. S. Corps of Engineers to incorporate public involvement avoids the problem definition stage, and gives early emphasis on identifying alternatives and evaluating the consequences of these alternatives in terms of achieving desired objectives (Sargent 1972). For small group interactions, the problem formulation and plan evaluation stages are believed to be the most critical points for public involvement (Delbecq and Van de Ven 1971).

6. Seek to involve the full range of publics affected by the issue. Both proponents and opponents of agency policies should be invited to express their views. To accomplish such a goal is difficult because some groups are not willing and capable of organizing and expressing their views.

The question of interest representation is a vitally important consideration in any public involvement undertaking. Recent research indicates that participation by interest groups, while not representative in terms of socioeconomic characteristics, have the same opinions on environmental issues as the general public. However, the major difference is that interest group participants are more willing to take action (Wilkinson 1974). Certainly, further research is needed to substantiate these results in a variety of situations.

With respect to interest representation on a geographic basis, local interests often dominate public input (Stankey et al. 1975). Thus, special efforts may be necessary to secure input from regional and national interests, when the issue is judged to have impact at those levels.

7. Select the appropriate approaches to obtaining public involvement at various stages in the decision making process. For example, opinion polling appears useful at an early stage to learn public awareness of the problem while workshops and conferences would be valuable after tentative consideration has been given to issues and alternatives.

8. Seek to sustain a high level of involvement but not necessarily continuous involvement of the same individuals. It is difficult to maintain the interest and commitment of everyone throughout the decision making process. People generally have many competing claims on their time (Sewell 1974).

9. Communicate information to affected publics with fidelity so that citizens may become cognizant of the consequences of various solutions. Public involvement must be preceded by a great effort to inform and educate the citizenry. In this regard, a person must: (1) receive accurate and unbiased information from the agency regarding the problems and issues, (2) know the consequences of the alternative solutions, and (3) be able to accurately express his preferences for the alternatives and the values he associates with them.

It is particularly important that an agency clearly define the issues to avoid being accused of misrepresentation of intent by those outside the agency. Also, as Haefele (1973:180) has stated, "how an issue is framed determines not only which people are for it and which against. . .but also the intensities of feeling pro or con." In addition, an agency should seek a clarification of public preferences through education rather than "selling" a single viewpoint (Swan 1974). This need to clearly define issues and to clarify public preferences in public involvement suggests a new and important role for information and education personnel in relation to agency decision making (Cutler 1974).

10. Allow adequate time for the public to respond to the issue as a means to assuring accurate and complete input. It has been observed that it takes time before the full implications of a decision become apparent. In many cases, unfortunately, it is only after implementation of the decision that people realize the consequences of it.

11. Request the assistance of social scientists in the collection and analysis of public preferences. Assessment of public preferences is a complex task and requires the skill of persons familiar with social science methods and concepts. See Hendee et al. (1974) for an excellent framework for incorporating public involvement into agency decision making.

12. While public preferences are a vital consideration in agency decision making, constraints such as legal mandates, ecological issues, resource capability, economic problems, etc. must also be considered in the decision. Public involvement requires the weighing of public preferences, among other factors, to arrive at a management decision. Some writers say that it also requires the granting of actual influence over the content of decisions to groups affected by those decisions, which implies that being cognizant of the preferences is insufficient. It must include the preferences "in the decision itself" (Irland and Vincent 1974). Considering the variety of preferences expressed by various individuals and interest groups, it may be impossible to accommodate all these views in the decision. This is particularly the case, for example, for the management policies dealing with the administration of the Wilderness Act of 1964 where both preservation and limited human use are explicit objectives of the Act. Although preferences may be expressed for providing for more intensive recreational uses, these preferences cannot be accommodated because of legal mandates (Stankey 1972a). These preferences may, however, indicate that there is an unfulfilled societal need and efforts should be made to accommodate this need either by amending the Act or by other actions.

In summary, effective public involvement requires that the manager: (1) know the preferences of individuals and groups affected by a decision, (2) consider these preferences and other factors in making a decision, (3) know who gains and who loses by particular decisions, and (4) communicate the rationale for a decision to affected publics.

APPROACHES

There are a variety of techniques that have traditionally been used for obtaining public involvement. They range from those receiving input on a massive scale (e.g., public meetings, hearings, soliciting written input) to small groups (e.g., workshops, ad hoc committees, advisory groups) to individuals (e.g., key contacts).

There is general agreement in the literature that there is not a single best technique for obtaining public input. Each technique has its advantages and disadvantages, which have been described by Hendee et al. (1973), Bultena and Rogers (1973) and U. S. Forest Service (1974). Collection techniques can be evaluated in terms of a number of criteria, for example: (1) how well are the interests represented; (2) how useful are the techniques in terms of the goals sought; (3) what range, specification, and intensity of preferences and values are communicated; (4) are personal preferences and values clarified; (5) how effective is the technique in reducing group conflict and achieving a satisfactory solution; and (6) does it produce results commensurate with the effort.

Different techniques for obtaining public input are more effective at some stages than at others. For example, interviewing "key" persons early in the planning process seems to be effective in identifying goals and objectives. Public hearings, on the other hand, are useful for obtaining reaction to alternatives, but tend toward an adversary process and generally do not lead to mutual understanding or consensus.

Evidence seems to indicate that some techniques are more frequently used than others. A recent study by Hendee et al. (1973) showed that public meetings, key contacts, agency reports, and mass media were the most frequently used approaches to public involvement. Similar results were obtained by Davis et al. (1975) who found that public hearings, advisory boards, and mass media were the most frequently used techniques.

Opinion polling is only infrequently used by natural resource agencies as a public involvement technique (Bultena and Rogers 1973, 1974). This limited use occurs despite the fact that opinion polls, when conducted by in-depth interviews, have a number of advantages over commonly used techniques. For example, they : (1) place the problem in context and permit the individual to reveal preferences not only among those items mentioned by the interviewer but for others as well; (2) remove certain biases inherent in some techniques, e.g., public hearings usually express the views of only a few individuals and reveal primarily what people do not want rather than what they would prefer; (3) reveal the preferences of the "silent majority," which might not be recorded; and (4) indicate the extent to which the nature of a problem is incorrectly perceived (Sewell 1971).

Considering the limited number of techniques now believed to be used by agencies, there seems to be a need to develop and use a variety of new techniques for obtaining public input (Wagner and Ortolano 1975).

A relatively new mass-oriented technique developed by the Seattle District of the U. S. Corps of Engineers is a public information brochure for communicating information to the public and receiving a response. The responses provide a basis for a revised brochure, which is distributed and subsequent iterations occur. A brochure typically contains: (1) background of past studies, (2) a summary of the alternatives with the pros and cons of each alternative, (3) a matrix displaying the consequences of each alternative for each public objective, (4) a listing of contributors, and (5) a glossary of technical concepts. Individuals can respond to the brochure by adding a pro or con to the list, and rebuttal space is provided across from each pro or con. This brochure is utilized as a latter part of the "fishbowl" planning process (Sargent 1972).

In addition to the Seattle District brochure, the Inland Lakes Project research group used a brochure with "mail response forms" to obtain such citizen input as seriousness of problems, individual actions to alleviate problems, and willingness to take action. As a response to the "mail response forms," two brochures were prepared and disseminated to the community. One of these brochures discussed ecological concepts and the other discussed problems and guidelines for community action (Fulton 1971).

Brochures appear useful at all stages of the planning process. They are useful for disseminating information, educating publics, and obtaining reactions to information presented.

Additional new techniques reflect input from small group research. The Delphi technique, for example, involves the use of questionnaires, which are developed by staff and completed individually by a panel. Participants in the Delphi technique are physically dispersed and do not meet face-to-face for group problem-solving activities. The purpose of the technique is to elicit the values of the participants and discover the basis of differences in values. It also is useful in ranking alternative actions.

The nominal group technique, like the Delphi technique, is particularly useful for obtaining the views from people of diverse backgrounds and perspectives. The procedure for the nominal group technique is as follows: (1) individual members first silently and independently generate their ideas on a problem in writing, (2) each individual presents one of his ideas to the group without discussion, (3) these ideas are summarized in a terse phrase and written on the blackboard or sheet of paper on the wall, (4) ideas are discussed for purposes of clarification and evaluation, and (5) ideas are silently voted upon by individuals using a ranking or rating procedure. The "group decision" is the pooled outcome of the individual votes.

The nominal group technique appears to be equally effective as the Delphi method in terms of the quantity of ideas generated and the perceived satisfaction of participants. The conventional interacting or discussion group appears less effective than either the nominal group or Delphi techniques (Van de Ven and Delbecq 1974).

The nominal group technique was used by the National Park Service to obtain regional goals and priorities for a thirteen county area in North Carolina and Tennessee surrounding the Great Smoky Mountains National Park (Brodie and Falk 1973). The Bureau of Land Management is using it as a training device for field personnel. It has also been tested elsewhere as a citizen involvement technique (Dane County Regional Planning Commission 1971, Institute for Environmental Studies 1975).

Once public input has been obtained, techniques to code, analyze, store and retrieve input are used. The U. S. Forest Service has developed a system called CODINVOLVE for this purpose and the system has been used in relation to many roadless area reviews and environmental statements (Clark et al. 1974, Clark and Stankey, in press). Content analysis is a technique which might be recommended for analyzing content of letters and other printed material. It has been used, for example, by Stankey (1972b), Middaugh (1973), and Erickson (1973).

RESEARCH NEEDS AND APPLICATION

Research Needs

Much of the public involvement research to date has not been a comparative evaluation of alternative approaches, but rather a description of case studies such as the Susquehanna Communication-Participation study (Borton and Warner 1974). Lacking comparative evaluations, it is difficult to prescribe any "formulas" for public involvement. Cooperation of agency administrators is vitally needed to permit experimentation with various approaches. The research on the nominal group and Delphi approaches being conducted by Van de Ven and Delbecq (1974) is an excellent example of the kind of experimental research desired.

Needed research to guide the development of public involvement activities has been described in detail by Stankey et al. (1975). Some of the more important research needs are outlined below:

1. Amount of Public Involvement. Empirically founded criteria need to be developed to guide decisions on "when" and "how much" input is needed.

2. Techniques of Collecting and Analyzing Public Input. What alternative collection techniques are possible and what are the benefits and costs of these techniques? What are the advantages and disadvantages of these techniques at each stage in the decision making process? How does the quality of opinion vary with collection technique? What techniques can be used to analyze information?

3. Participant Characteristics and Motivation. What kinds of people are participating in resource decisions? Does involvement reduce anomie and powerlessness? Why and how do people get involved? What techniques are effective at obtaining representation of all interests affected by a decision?

4. Group Interactive Mechanisms. What are the costs and benefits of various interactive mechanisms between managers and the public? What mechanisms are most effective for exchanging information between managers and the public? What mechanisms tend to reduce conflict?

5. Information Dissemination Techniques. What techniques can be used to communicate issues to the public? How does the definition of the issue affect the kinds of participants that become interested in the issue? What techniques are effective at displaying the consequences of alternative courses of action?

6. Decision Making Procedures of Resource Agencies. To what extent are state and local agencies utilizing public involvement procedures in decision making? What techniques are being utilized?

Barriers to Application of Research Results

There are a number of barriers that are likely to affect the future implementation of research.

1. The attitudes of professionals toward the value of public input in decision making. Professionals often believe they know what is best for the public--and in some cases they are probably right. But to go blindly along without full knowledge of the various interests and the benefits and losses generated by decisions seems insufficient for acceptable public administration.

2. The costs in terms of money and time. For example, preparation of information and education materials and programs is expensive. To permit sufficient time for effective involvement may be too time consuming for an agency. In many instances, the pressures to make a quick decision do not permit use of effective public involvement techniques and the public has to be involved too late in the process. Direct involvement techniques such as workshops are costly for the participant as well, and the agency will have to expend considerable efforts to assure sufficient involvement.

3. Many managers lack the interest and the skills required for public involvement (Stankey et al. 1975). Many managers have chosen the resource management profession because they like to be away from citizens, not interact with them. Thus agencies should consider training sessions for defining various roles in the decision making process and training for effectiveness of public involvement (Folkman 1973). Experience with the actual process itself is beneficial too. As Hendee et al. (1973) have indicated, "experience with public involvement tends to reinforce a commitment to it."

4. The uncertainty of the results of public involvement. Some interest groups are likely taking advantage of involvement and are utilizing it to gain power and influence. Also, public involvement gives no assurances that an interest group will still not subsequently challenge decisions in court.

LIST OF REFERENCES[2/]

Aleshire, Robert A. 1970. Planning and citizen participation: costs, benefits and approaches. Urban Aff. Quart. 5(4):369-393.

* Allee, David J. 1974. The role of public involvement in water resources planning and development. Tech. Completion Rep. No. 79, 160 p. Cornell Univ. Water Resources and Marine Science Center, Ithaca, N. Y.

Alston, Richard M. 1972. Forest goals and decision making in the Forest Service. USDA For. Serv. Res. Pap. IN T-128, 84 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Arnstein, S. R. 1969. A ladder of citizen participation. J. Amer. Inst. of Planners 35(4):216-224.

Ashton, Peter M. 1974. Accountability of public water agencies: Legal institutions for public interaction, p. 51-75. In Proceedings: Conference on public participation in water resources planning and management, ed. by James M. Stewart, 194 p. N. C. Water Resources Res. Inst., N. C. State Univ., Raleigh.

* Behan, R. W. 1966. The myth of the omnipotent forester. J. For. 64(6): 398-400, 407.

__________. 1971. Wilderness decisions in Region I., U. S. Forest Service: A case study of professional bureau policy making. Unpubl. PhD. Thesis, Univ. of Calif., Berkeley.

* Bishop, A. B. 1970. Public participation in water resources planning. U. S. Army Inst. for Water Resources Rep. 70-7, 109 p. Alexandria, Va.

Biswas, Asit K. 1974. Socioeconomic considerations in water resources planning. Water Resources Bull. 9(4):746-754.

Bolle, A. W. 1971. Public participation and environmental quality. Natur. Resources J. 11:497-506.

* Booher, David E. 1975. Citizen participation in planning: Selected interdisciplinary bibliography. Counc. of Plann. Librarians Exch. Bibliogr. No. 718, 20 p. Monticello, Ill.

[2/] The most important references are indicated by an asterisk.

* Borton, Thomas E., and Katherine P. Warner. 1974. Involving citizens in water resources planning: the communication-participation experiment in the Susquehanna River basin, p. 248-270. In Environmental education: Strategies toward a more livable future, ed. by James A. Swan and William B. Stapp, 249 p. New York: John Wiley and Sons.

* Bregha, Francis J. Public participation in planning policy and programme, 40 p. Community Develop. Br., Community Serv. Div., Min. of Community and Soc. Serv., 400 Univ. Ave., Toronto, Ont.

Brodie, D. Q., and R. Frank Falk. 1974. Great Smoky Mountains National Park: Regional planning effort, 35 p. Dep. of Sociol., Univ. of Denver, Denver, Colo.

* Buchanan, J. M., and G. Tullock. 1962. The calculus of consent: Logical foundations of constitutional democracy, 361 p. Ann Arbor: The Univ. of Mich. Press.

Bultena, Gordon L., and John C. Hendee. 1972. Forester's views of interest group positions on forest policy. J. For. 70(6):337-342.

* ________________, and David L. Rogers. 1973. Studies of public preferences and group interactions to guide land use planning and control, p. 351-375. In Papers of the land use planning seminar: Focus on Iowa. Iowa State Univ. Center for Agr. and Rural Develop., Iowa State Univ., Ames, Iowa.

________________, ______________., and Vince Webb. 1973. Public response to planned environmental change: A study of citizens' views and actions on the proposed Ames Reservoir, 108 p. Dep. of Sociol. and Anthropol., Iowa State Univ., Ames, Iowa.

* ________________, 1974. Dynamics of agency-public relations in water resource planning, p. 125-149. In Water and community development: Social and economic perspectives, ed. by Donald R. Field, James C. Barron and Burl F. Long, 302 p. Ann Arbor, Michigan: Ann Arbor Science Publishers Inc.

________________, and ______________. 1974. Considerations in determining the public interest. J. Soil and Water Conserv. 29(4):168-173.

* Burke, Roy III., James P. Heaney, and Edwin E. Pyatt. 1973. Water resources and social choices. Water Resources Bull. 9(3):433-447.

Chevalier, Michel, and T. J. Cartwright. 1971. Public involvement in planning: The Delaware River case. In Perceptions and attitudes in resources management, ed. by W. R. Derrick Sewell and Ian Burton, 147 p. Information Canada: Ottawa, Ont.

* Clark, Roger N., George H. Stankey, and John C. Hendee. 1974. An introduction to Codinvolve: A system for analyzing, storing, and retrieving public input to resource decisions. USDA For. Serv. Res. Note PNW-223, 16 p. Pac. Northwest For. and Range Exp. Stn., Portland, Ore.

_______________, _________________. Analyzing public input to resource decisions: Criteria, principles, and case examples of the Codinvolve system. Natur. Resour. J. (1976, in press).

Cole, Richards L. 1974. Citizen participation and the urban policy process. Lexington, Mass.: Lexington Books.

* Connor, Desmond M. 1974. Citizens participate: An action guide for public issues, 64 p. Oakville, Ont.: Develop. Press.

Conservation Foundation. 1972. National parks for the future: An appraisal of the national parks as they begin their second century in a changing America, 254 p. Washington, D.C.

* Copp, Howard D. 1973. More responsive water planning is possible. Eng. Ext. Serv., Bull. No. 330, 61 p. Wash. State Univ., Pullman.

Cutler, M. Rupert. 1974. New role for government information and education personnel. Trans. of the 39th N. Amer. Wildlife and Natur. Resour. Conf., 397-405.

Dane County Regional Planning Commission. 1971. Citizen participation project: Summary and analysis, 122 p. Madison, Wis.

* David, E. L. 1972. Public participation in decision making. Sea Grant Tech. Rep. No. 26, 13 p. Sch. of Natur. Resour., The Univ. of Mich., Ann Arbor.

* Davis, Adam Clarke, Jill Anderson, and Richard I. Gough. 1975. Alternative information and interaction approaches to public participation in water resources decision making: A state-of-the-arts report. N. C. Water Resources Res. Inst. Rep. No. 106, 40 p. N. C. State Univ., Raleigh.

Davis, L. S. and W. R. Bentley. 1967. The separation of facts and values in resource policy analysis. J. For. 65(9):612-620.

Delbecq, André L. and Andrew H. Van de Ven. 1971. A group process model for problem identification and program planning. J. Appl. Behav. Sci. 7(4):466-492.

* Downs, Anthony. 1957. An economic theory of democracy. 310 p. N. Y.: Harper and Brothers.

* Draper, Dianne. 1973. Public participation in enviornmental decision making. Counc. of Plann. Librarians Exch. Bibliogr. No. 396, 27 p. Monticello, Ill.

* Dysart, Benjamin C., III. 1974. Education of planners and managers for effective public participation, p. 77-127. In Proceedings: Conference on public participation in water resources planning and management, ed. by James M. Stewart, 194 p. N. C. Water Resources Res. Inst., N. C. State Univ., Raleigh.

Erickson, David L. 1973. "The wolf men," p. 283-287. In Interpreting environmental issues, ed. by Clay Schoenfeld, 290 p. Madison, Wis.: Dembar Educ. Res. Serv., Inc.

Etzioni, A. 1967. Toward a theory of societal guidance. Amer. J. Sociol. 72(2):173-187.

Flack, J. Ernest and David A. Summers. 1971. Computer-aided conflict resolution in water resource planning: An illustration. Water Resources Res. 7(6):1410-1414.

* Folkman, William S. 1973. Public involvement in the decision-making process of natural resource management agencies: With special reference to the Pacific Northwest. Public Affairs Pap. No. 3, 29 p. Inst. of Gov. Res., Univ. of Wash., Seattle.

Forest, Laverne B. 1974. Attitudes toward scenic corridor development - Shawnee National Forest: A study of involvement input using content analysis procedures, 65 p. Dep. of Agr. and Ext. Educ., Univ. of Wis., Madison.

Fox, Irving K. 1973. Some political aspects of the relationship between large-scale interbasin water transfers and environmental quality, p. 413-424. In Environmental quality and water development, ed. by Charles R. Goldman et al., 510 p. W. H. Freeman and Company, San Francisco.

* ____________, and Lyman F. Wible. 1973. Information generation and communication to establish envrionmental quality objectives. Natur. Resource J. 13(1):134-149.

* Frauenglass, Harvey. 1971. Environmental policy: Public participation and the open information system. Natur. Resources J. 11(3):489-496.

Frear, S. T. 1973. Confrontation vs. communication: Confessions of a government PR man. J. For. 71:650-652.

Freeman, David M. 1972. Politics of planning and the problem of public confidence: A sociology of conflict approach. Proc. Soc. Amer. For., 184-199.

* Fulton, Jerome K. 1971. Development and evaluation of citizen participation techniques for inland lake and shoreland management. Huron River Watershed Counc., 415 West Wash. St., Ann Arbor, Mich. 48103

Gale, R. P. 1973. Communicating with environmentalists: A look at life on the receiving end. J. For. 71:653-655.

Godbey, Geoffrey and Richard Kraus. 1973. Citizen participation in urban recreation decision making. Comm. Develop. J. 8:155-160.

* Haefele, Edwin T. 1973. Representative government and environmental management, 188 p. Baltimore: The Johns Hopkins Univ. Press.

Hagevik, George H. 1970. Decision making in air pollution control, 217 p. N. Y.: Praeger Publishers.

* Hart, David K. 1972. Theories of government related to decentralization and citizen participation. Public Admin. Rev. 32:603-621.

* Havlick, Spenser W. 1970. The construction of trust: An experiment in expanding democratic processes in water resource planning. Water Spect. 1(2):13-19.

Hendee, John C., and Robert Harris. 1970. Foresters' perception of wilderness - user attitudes and preferences. J. For. 68:759-762.

* ____________, Robert C. Lucas, Robert H. Tracy, Jr., Tony Staed, Roger N. Clark, George H. Stankey, and Ronald A. Yarnell. 1973. Public involvement and the Forest Service: Experience, effectiveness and suggested direction, 163 p. For. Serv., U. S. Dep. of Agr., Washington, D. C.

* ____________, R. N. Clark, and G. H. Stankey. 1974. A framework for agency use of public input in resource decision making. J. of Soil and Water Conserv. 29(2):60-66.

* Henning, Daniel H. 1974. Environmental policy and administration, 205 p. N. Y.: Amer. Elsevier Publ. Co., Inc.

Holden, M. 1966. Pollution control as a bargaining process: An essay on regulatory decision making. Cornell Univ. Water Resources Center Publ. No. 9, Ithaca, N. Y.

Ingram, Helen. 1971. Patterns of politics in water resources development. Natur. Resources J. 11(1):102-118.

____________. 1973. Information channels and environmental decision making. Natur. Resources J. 13(1):150-169.

Institute for Environmental Studies. 1975. A case study of citizen participation in resource planning: The Crawford County critical resource information workshop. IES Rep. 44, 61 p. Univ. of Wis., Madison

* Irland, Lloyd C., and J. Ross Vincent. 1974. Citizen participation in decision making - a challenge for public land managers. J. Range Manage. 27(3):182-185.

Jackson, John S., III., and William L. Shade. 1973. Citizen participation, democratic representation and survey research. Urban Aff. Quart. 9(1):57-89.

Johnson, William K. 1974. Approaches for developing alternatives in planning. Water Resources Bull. 10(5):1017-1022.

* Kasperson, R. E. 1969. Political behavior and the decision-making process in the allocation of water resources between recreation and municipal use. Natur. Resources J. 9(2):176-211.

Kloman, Erasmus H. 1975. A minisymposium: Public participation in technology assessment. Public Admin. Rev. 35(1):67-81.

* Lee, Jack M., Jr. 1972. Citizen participation in wildlife management decision making: The squirrel hunting season as an example, 163 p. Unpubl. Master Thesis, Va. Polytechnic Inst. and State Univ., Blacksburg, Va.

Lord, William B., and Maurice L. Warner. 1973. Aggregates and externalities: Information needs for public natural resources decision making. Natur. Resources J. 13(1):106-117.

Lucas, Alastair R., and Patrick A. Moore. 1973. The Utah controversey: A case study of public participation in pollution control. Natur. Resources J. 13:36-75.

McKenzie, Linda (ed.) 1972. The grass roots and water resources management. State of Wash. Water Res. Center. Wash. State Univ., Pullman.

* Middaugh, Geoffrey B. 1973. Effectiveness of selected Forest Service public meetings and implications for decision making. Unpubl. Masters Thesis. Dep. of For. Sci., Utah State Univ., Logan.

Morley, C. G. 1974. Public participation: A right to decide, p. 509-524. _In_ The allocative conflicts in water resources management. Aggasiz Center for Water Stud., The Univ. of Man., Winnipeg, Can.

Ogden, D. M. 1970. Wildland policy decisions - by whom? J. For. 68(4):200-204.

* Olson, Mancur. 1965. The logic of collective action: Public goods and the theory of groups. 176 p. Cambridge, Mass: Harvard Univ. Press

* Ontario Provincial Government. 1974. Analysis and design of public participation programme evaluation in Ontario, 25 p. Office on Community Consult., Min. of Comm. and Soc. Serv., Toronto, Ont., Can.

* O'Riordan, T. 1971a. Perspectives on resource management. 183 p. London: Pion Limited.

* __________. 1971b. Public opinion and environmental quality: A reappraisal. Environ. and Behav. 3(2):191-214.

* __________. 1971c. Towards a strategy of public involvement, p. 99-110. In Perceptions and attitudes in resources management, ed. by W. R. Derrick Sewell and Ian Burton, 147 p. Inform. Can., Ottawa, Ont.

* Ortolano, Leonard. 1974. A process for federal water planning at the field level. Water Resour. Bull. 10(4):766-778.

* _______________. 1975. Water resources decision making on the basis of the public interest. Dep. of Civil Eng., Stanford Univ., Stanford, Calif.

Ostrom, Vincent and Elinor Ostrom. 1971. Public choice: A different approach to the study of public administration. Publ. Admin. Rev. 31(2): 203-215.

* Polchow, Alfred, Sue Sampson, and Lawrence S. Davis. Methodology and effectiveness of administrative public involvement: Abstracts and bibliography, 149 p. Dep. of For. and Outdoor Rec., Utah State Univ., Logan.

Powell, Norman John. 1967. Responsible public bureaucracy in the United States. 191 p. Boston: Allyn and Bacon, Inc.

* Public Land Law Review Commission. 1970. One third of the nation's land, 342 p. U. S. Govt. Printing Office, Washington, D.C.

Rahm, Neal M. 1970. Public participation in national forest management decisions. J. For. 68(4):205-207.

* Reich, Charles A. 1966. The law of the planned society. The Yale Law J. 75(8):1227-1270.

Reimers, Mark Alan. 1973. Involving the public in the land planning of the Rock Creek drainage. Unpubl. Masters Thesis, Dep. Natur. Res., Cornell Univ., Ithaca, N. Y.

* Reinke, K. B., and B. Reinke. 1973. Public involvement in resource decisions: A national forest seeks public input for recreation development. J. For. 71:656-658.

Reynolds, J. P. 1969. Public participation in planning. Town Plann. Rev. 40(2):131-148.

* Rich, Stuart U. (ed.) 1973. Public relations in an era of public involvement: Challenge for the timber industry. 104 p. Proc. of a Curr. Issues Conf., March 20, 1973. Eugene, Ore.: The Univ. of Ore. Press.

Rickson, R. E., P. J. Tichenor, G. A. Donohue, and C. E. Olien. 1975. Role of the scientist technician in water policy decisions at the community level: A study in purposive communication. Water Resour. Res. Cent. Bull. 79, 51 p. Univ. of Minn., Minneapolis.

Ross, Charles R. 1973. Decision making at local, state, federal, and international levels, p. 398-412. In Environmental quality and water development, ed. by Charles R. Goldman, James McEvoy III, and Peter J. Richerson, 510 p. San Francisco, Calif.: W. H. Freeman and Co.

* Ross, Peggy J. 1974. Education of publics for participation in water resource policy and decision making. In Proceedings: Conference on public participation in water resources planning and management, ed. by James M. Stewart, 194 p. N. C. Water Resour. Res. Inst., N. C. State Univ., Raleigh.

* Sargent, Howard L., Jr. 1972. Fishbowl planning immerses Pacific Northwest citizens in Corps projects. Civil Eng. - ASCE: Sept.:54-57.

Schafer, Arthur. 1974. Citizen participation, p. 487-508. In The allocative conflicts in water resources management, Aggasiz Center for Water Stud. The Univ. of Man., Winnipeg, Can.

Scoville, Anthony. 1973. Citizen participation in state government: A summary report, 26 p. Environ. Plann. Infor. Center, 26 State Street, Montpelier, Vt.

* Sewell, W. R. Derrick. 1971. Integrating public views in planning and policy making. In Perceptions and attitudes in resources management, ed. by W. R. Derrick Sewell and Ian Burton, 147 p. Infor. Can., Ottawa, Ont.

* ____________________. 1974. Perceptions, attitudes and public participation in countryside management in Scotland. J. Environ. Manage. 2(3):235-257.

* Smith, Richard W. 1973. A theoretical basis for participatory planning. Policy Sci. 4:275-296.

Stamm, Keith R., and John E. Bowes. 1972. Communication during an environmental decision. J. Environ. Educ. 3(3):49-55.

Stankey, George H. 1972a. A strategy for the definition and management of wilderness quality, p. 88-114. In Natural environments: Studies in theoretical and applied analysis, ed. by John V. Krutilla, 352 p. Baltimore, Md.: The Johns Hopkins Univ. Press.

______________. 1972b. The use of content analysis in resource decision making. J. For. 70(3):148-151.

* ______________, John C. Hendee, and Roger N. Clark. 1975. Applied social research can improve participation in resource decision making. Rural Sociol. 40(1):67-74.

Swan, James A. 1974. Some human objectives for environmental education, p. 25-41. In Environmental education: Strategies toward a more livable future, ed. by James A. Swan and William B. Stapp, 349 p. New York: John Wiley and Sons.

Twight, Ben W., and William R. Catton, Jr. 1975. The politics of images: Forest managers vs. recreation publics. Natur. Resour. J. 15(2):297-306.

* U. S. Army Corps of Engineers. Public brochure: Alternatives and their pros and cons, small boat harbors Elliot Bay, Seattle Harbor, Seattle, Washington, 57 p. Seattle Dist. 1519 Alashan Way South, Seattle, Wash. 98134.

* U. S. Forest Service. 1974. Guide to public involvement in decision making, 22 p. U. S. Govt. Printing Office, Washington, D.C.

* Van de Ven, Andrew H., and André L. Delbecq. 1972. The nominal group as a research instrument for exploratory health studies. Amer. J. of Public Health, 337-342.

* ______________, and ______________. 1974. The effectiveness of nominal, delphi, and interacting group decision making processes. Acad. of Manage. J. 17(4):605-621.

* Verba, Sidney. 1967. Democratic participation. Ann. of the Amer. Academy of Polit. and Soc. Sci. 373:53-78.

* ______________, and Norman H. Nie. 1972. Participation in America: Political democracy and social equality. N. Y.: Harper and Row.

* Wagar, J. Alan, and William S. Folkman. 1974. Public participation in forest management decisions. J. For. 72(7):405-407.

* Wagner, Thomas P., and Leonard Ortolano. 1975. Analysis of new techniques for public involvement in water planning. Water Resour. Bull. 11(2):329-343.

* Warner, Katherine P. 1971. A state-of-the-arts study of public participation in the water resources planning process, 235 p. Nat. Tech. Inform. Serv. Rep. PB 204, 245. Springfield, Va.

Warner, Keith W. 1973. Voluntary associations and individual involvement in public policy making and administration, p. 239-257. In Voluntary Action Research: 1973, ed. by David H. Smith. Lexington, Mass.: D. C. Heath and Co.

* Wengert, Norman. 1955. Natural resources and the political struggle. 71 p. N. Y.: Doubleday.

* _______________. 1971. Public participation in water planning: A critique of theory, doctrine, and practice. Water Resour. Bull. 7(1):26-32.

* _______________. 1974. Where can we go with public participation in the planning process? p. 109-126. In The role of public involvement in water resources planning and development, ed. by David J. Allee, 160 p. Cornell Univ. Water Resour. and Marine Sci. Center, Ithaca, N. Y.

White, Gilbert F. 1973. Public opinion in planning water development, p. 157-169. In Environmental quality and water development, ed. by Charles R. Goldman, James McEvoy III, and Peter J. Richerson, 510 p. San Francisco: W. H. Freeman and Company.

* Wilkinson, Paul. 1974. The role of the public in environmental decision making, p. 232-250. In Protecting the environment: Issues and choices - Canadian perspectives, ed. by O. P. Dwivedi. Toronto, Ont.: Copp Clark Publishing.

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A CRITIQUE OF THE PAPER ENTITLED

"PUBLIC INVOLVEMENT IN RECREATION RESOURCES DECISION MAKING"

Owen T. Jamison [1]

The authors have done a creditable job in describing the state of the art in public involvement. They have asked the right questions and brought out the shortcomings, problems, and research needs. My principal regret about this paper, and hence the state of the art, is that there is not more new research and techniques to report. Most of the "relatively new" public involvement techniques have been in use by the agencies for some time. This strongly points up the need for much more effort in this vital arena.

With an awakened (or aroused) and interested public we all know that public involvement must be much more than running a project or program by selected keymen. It is, however, relatively new to most natural resource agencies. There is much to be learned and we well know that the process will be hard.

The Forest Service has had considerable experience in public involvement. Major recent efforts in national programs such as Roadless Area Review and Evaluation (RARE), Environmental Program for the Future (EPFF), and Forest and Rangeland Renewable Resource Planning Act (RPA), plus inumerable regional and local programs, have shown us that the authors' cited problems are very real and not overstated.

Time and money are critical problems. I disagree with the authors that agency administrators cannot afford the time and cost of public involvement on many official actions. This assumes significant actions, of course. We cannot afford not to afford the time and cost. Generally, court tests are more time and money consuming than public involvement.

I do not, however, downplay the time and cost factor. Our evolving experience in RPA bears this out. It takes much time and money to prepare and disseminate 150 tons of public information in 2½-inch sets. Of course this just starts the process. Public meetings, analysis of public input, revisions, final documents, etc., add to the load.

While not disagreeing with the authors on research needs, here are my ideas on priorities:

1. What should be presented to the public and how? Most environmental statements are too lengthy and technical for even other technical people to assimilate.

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2. How can we gather input from the vast public who are involved in the decision but usually not represented? How can we be sure everyone is being heard?

3. How can we better interpret what we receive? This question does not belittle the work that has been done in this area. It just shows my perception of its importance.

4. How can we better cross-pollinate between agencies for a more effective, understandable and uniform approach to the public?

5. How do we keep research focused on the problems as perceived by managers?

6. How do we establish clearer communications with secondary fields?

7. Can we (and how) keep public involvement on a cost-effective basis?

NEW ROLES FOR GOVERNMENT AND INDUSTRY IN OUTDOOR RECREATION

W. F. LaPage[1]

Abstract.--The examination of some possible future options for public parks and recreation agencies is necessitated by 3 hard facts: 1. the rising dominance of the private sector, 2. the emerging public revolt against increased tax supported programs, and 3. the trend toward greater public involvement in agency decision-making. A central role for public parks and recreation agencies is seen to be that of a cooperator with the private sector, taking such forms as joint development planning, increased use of concession-operated public facilities, and new directions for public parks and recreation programs.

> "Everyone wants the government to be bold and imaginative and infallible -- all at the same time. It will never happen"
>
> John W. Gardner, in "No Easy Victories"

The recent evolution of outdoor recreation in America could be described from several different vantage points: greater public demands for more and more recreational services, the increasing dependence upon expensive equipment and highly developed facilities, the expanding role of parks and recreation professionals, and the proliferation of public agency plans, programs, and purchases of land. But perhaps the most dramatic adjustment has been the shift in the relative "market shares" served by public recreation agencies and private enterprise. From a position of near obscurity little more than a generation ago, private enterprise today outnumbers and outperforms the public sector in the provision of several kinds of outdoor recreation services.

This changing cultural view of outdoor recreation, from that of a purely social good to the image of profit making "commodity", carries with it a number of potential identity crises for public outdoor recreation agencies. Now, as this private enterprise trend converges with other social trends of wide-spread public resistance to further expansion of tax-supported programs, and increased public involvement in agency decision-making, an examination of new roles for public recreation agencies is timely if not imperative.

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Coordinator - Cooperator

Dominant among these "new" agency roles is that of a coordinator and cooperator with the private sector. This is a role which is widely recognized as a legitimate one among recreation and parks professionals. But it is also a role which is seldom funded or explicitly described in the agency's legislative mandate. Consequently it is a role which receives a lot of attention as "policy" but has few operational guidelines in practice.

Effective coordination and cooperation requires rapid and reliable systems for (1) determining what is going on outside of the agency and (2) arriving at a consensus among agency clientele on appropriate responses. Such systems do not exist and I know of no serious efforts to develop them. For example, the majority of State Park agencies determine the need for new campsites by the presence of overcrowding at their own campgrounds. With very few exceptions, States do not survey the private sector prior to expanding their own capacities (Fuller, 1969).

Surveys of the private sector should not, however, be restricted to determinations of capacity and attendance. Types of facilities offered, fees charged, development plans, and public assistance needs, are items of information for any public agency which is serious about its coordinating and cooperating role. The possible elimination of public agency programs is as valid a goal as expansion, for the public administrator who is concerned about moving some of his budget and manpower away from duplicative activities and into new and innovative programs.

The development of information systems which will provide a basis for changing organizational direction should include the criterion of a minimal reporting burden on private enterprise. On-the-ground agency personnel frequently have a good idea of what nearby commercial developments are charging and what kinds of facilities they offer. Standardized observation techniques can increase the utility of such data. Observational data on nearby situations can be supplemented through a variety of sources such as State-wide comprehensive outdoor recreation plans, trade association brochures and bulletins, Chambers of Commerce, and an open-door agency policy. As local businessmen discover that their views are welcomed, and are in fact a source of public policy influence, a more desirable public-private recreation complex is certain to emerge. The agency's responsibility to the public is not served by ignoring or competing with one segment of that public.

Effective cooperation with the private sector will require expanded agency capabilities for promoting, conducting, purchasing, and interpreting recreation market research. Whether a public agency wishes to cooperate with the private sector or not, its need to improve its understanding of research will increasingly be felt as the numbers of recreation researchers and their printed output expands its influence in the profession. A further motivation for an improved research capability is the growing social insistence upon research-based impact assessments of all contemplated actions, including economic impacts. And, finally, as park agencies expand into presently under-developed areas, such as cultural programs and events, they will need some advance assessment of the market and subsequent analysis of program success (Ritchie and LaBreque, 1975).

The combination of agency willingness to change its policies, its practices, and its programs, plus the solid backing of the private sector will seldom be sufficient to produce organizational change. The approval of existing clientele groups, legislators, and budget directors is no less essential. Involving these publics and seeking a concensus from them will increasingly become a major agency effort rather than an occasional top-level activity.

Innovator - Experimentor

As private enterprise increases its capability to provide outdoor recreation services, both on its own land and through public land concessions, public agencies can begin to fill some of the immense gaps in the existing spectrum of recreation opportunities. Lloyd and Fischer (1972) have prescribed a program of providing better balance in the total array of outdoor recreation opportunities as the best way to alleviate current overcrowding at both ends of the concentrated-dispersed continuum. The middle ground between outdoor resorts and wilderness areas is a gold mine of opportunities for public recreation administrators to experiment with. It also represents the vast majority of public lands available for recreation to the person of average means.

Improved opportunities for cross-country skiing, bike trails, vehicle trails, and a wide variety of interpretive trails are some of the more common examples of needed recreation opportunities which can be legitimately supplied by public agencies. Such opportunities are seldom financially attractive to the private developer, but their public provision will tend to enhance the attraction and viability of near-by complimentary private exterprise. Dispersed picnicking sites, back-country tenting, "micro-wilderness" experiences, and aerial tramways to remote scenic spots (Julber, 1972), are further examples of mid-range developments. The Ozark Folk Center, developed by the Arkansas Department of Parks, is an outstanding experiment in preserving and encouraging the musical and crafts heritage of a region.

In addition to experimenting with new recreation services, public agencies need to experiment with new clientele groups. Most State Park agencies, for example, are well staffed with specialists in design, planning, construction, management, and promotion of outdoor recreation areas. These people could provide badly needed extension-type services to private recreation developers and to communities. The possibilities of direct competition with private consultants can be minimized by the types and intensities of services provided.

The past successes of public agencies in developing new recreation markets, and expanding them to the stage where they have commercial investment potential, provide models which should be easy to replicate. Today's immense downhill skiing market, and the now highly diversified camping market are results of early and successful public park innovations. Many other recreation markets can trace their evolution to similar beginnings. The problem is, as Peter Drucker (1973) describes it, that no success lasts forever. "A success which has outlived its usefulness may, in the end be more damaging than failure." It's time for many public park agencies to ask themselves if their tax-supported ski areas and campgrounds may have outlived their usefulness; and whether their manpower and resources might be better used to create new successes and stimulate whole new cycles of private investment.

Innovations in services must be matched with innovations in management. With a few exceptions, our public parks and recreation agencies have not developed reputations as management innovators. I almost hesitate to raise the subject of concession operations before a group of public park administrators. Their predictable negative reaction is usually based on heresay rather than personal experience; and badly out of date heresay at that! The subject of concessions on federally owned areas has been studied and restudied numerous times by Congress and the agencies. Past failures were due as much to a lack of agency support as to concessionaire incompetence. The private sector today has the expertise to manage public outdoor recreation services. And, I hope that public parks administrators have grown commensurate in their abilities to supervise performance contracts, and experiment with the concession concept.

The number and types of concessions on national and state recreation lands appears to have remained fairly constant in recent years (U.S. House of Rep., 1974). And, while several recent reports such as the Conservation Foundation's "National Parks for the Future" (1972) have recommended that concessions be phased out, the report of the Public Land Law Review Commission (1970) makes several recommendations to strengthen and expand concession operations on state and federal lands, including agency capital development, reduced fees and longer terms.

Of the nearly 1,800 concessions on Forest Service lands, 80 percent are either low investment low return type operations (back country packers) or high investment high risk types such as resorts and winter sports areas. Operations such as stores, swimming facilities, picnic sites, and camping areas account for less than 10 percent of all concession operations and far less than 10 percent of the available opportunities. Conversely, concessions on state recreation lands are almost exclusively the high volume type of activities such as eating places, stores, water activities, and overnight accommodations (U.S. House of Rep., 1974). The recurring observation that concession operations on federal lands are marginal investments at best may be totally a function of needlessly restrictive public policy.

As recently as 1968, in a National symposium on outdoor recreation planning, the view was expressed that: "The country has made the determination that it is in the public interest to provide outdoor recreation opportunities with public money. The task is to provide a basic outdoor recreation system within the reach of every citizen. There is an important role for private initiative but it is not a dominant role." The role of the private sector in recreation must be similar to its role in other areas where government provides the basics, like education for example" (Diamond, 1970). Any assessment of today's private enterprise role which arrived at a similar conclusion would have to be made in complete ignorance of such operations as the campground franchisor who provides more campsites than the entire National Park system. And, this is just one of 4 dozen franchise organizations in the camping field. Furthermore, if it is, in fact, our national goal to provide a basic outdoor recreation system which is within the reach of every citizen, it would be naive to assume that this could be accomplished without the private sector playing a major role.

Innovations in management need not be spectacular. Better systems of cost-accounting are needed so that more informed public decisions can be made. In a great many park systems today, it is virtually impossible to obtain any estimate (reliable or not) on the cost of providing such services as an overnight camping experience. Without this kind of factual information it is almost absurd to consider a change to concession operation, or to solicit public involvement on decisions of whether to expand or even continue agency campground operations. Accountability may prove to be one of the major public policy issues for our parks and recreation agencies in the years ahead through pressures from the private sector and citizen interest groups.

Advocate - Promoter

None of the roles that I have described - innovator, experimentor, stimulator, coordinator, cooperator - are really new for public recreation agencies; although they may need a little dusting off from time to time. However, none of these roles, or their potential accomplishments, can become a reality unless parks and recreation professionals are willing to revitalize their basic role and become activists for their cause. In recent years, the activist role in environmental-conservation concerns has slipped away from the professionals and now resides in citizen groups and in the courts.

The growth of public participation is vividly described as a paradox for the public administrator by Harlan Cleveland's succinct statement "How do you get everybody in on the act and still get some action?" (Cleveland, 1974). The era of participation is clearly an improvement over the days when nobody seemed to care what was done with public lands. But, just as clearly, if some of our past leaders had discussed their great ideas widely before launching them, most would probably have collapsed with dry rot awaiting a consensus that they would float.

Public participation can be viewed as a new leadership opportunity - developing real participatory roles and new styles of involvement. Or, it can degenerate into an endless series of plebescites in which "procedure becomes the surrogate for substance" in what Victor Thompson (Thompson, 1965) would call a "bureautic" or "bureaupathic" response. There is some evidence that citizen involvement is already being viewed as a convenient shield for avoiding the responsibility of making hard decisions by some of our private sector cooperators (LaPage, 1975).

The idea of being branded a "zealot" today is unattractive for most professionals. "Advocate" is the more acceptable term. If you look at the early leaders of most of our conservation and parks agencies, they were more than advocates! In fact, Anthony Downs (1967) hypothesizes that all bureaus are initially dominated by advocates or zealots. But, he also suggests a "Law of increasing conservatism" that all organizations become more conservative and more resistant to change as they grow older. Since most of our parks and recreation agencies are old organizations with long established routines it would be easy to be pessimistic about the possibilities for major innovations.

Breaking the Law of Increasing Conservatism requires both a conscious effort and a clearly established goal. It requires not just being an advocate for change, but being a promoter for some very specific changes. It requires not trying to satisfy everybody (which usually means satisfying nobody) but setting your sights on a specific share of the recreation market which you can most appropriately serve. Parks and recreation agencies more than most service institutions, find it very difficult to set priorities. And, when they do, the priorities may be the reverse of what would normally be good business practice. Programs which fail to produce get increased budgets precisely because of their failure, while the performers are assumed not to need any special attention (Drucker, 1973).

The budget is clearly a primary focus for organizational change. Obviously, nothing is accomplished unless scarce finances and manpower are concentrated where they are needed most. Citizen involvement, performance budgeting, and even suggestions for recreation voucher systems (Sears, 1975), are recognitions of this fact. But, they each run the risk of becoming procedure-bound.

It seems increasingly clear that the future administration of our public parks and recreation areas will take the form of a shared leadership. The professionally trained parks administrator can become the spark plug of a team including professional and citizen advocates, or he can become a technician carrying out the wishes of others and contributing toward a state of "participatory mediocrity". The dynamic leader is not the antithesis of participatory administration; in fact, he may be in demand more than ever.

Public participation is not an administrative tool. It is a style of administration. But, more than that, it is a "natural" for parks and recreation. Volunteer "advocate bureaucrats" could be enlisted to work within agencies in staff positions to help citizens gain access and present their views on critical decisions. Volunteer field workers have a long history of helping to develop trails and public recreation sites. Volunteer office staff would be a logical extension of this valued heritage. There are numerous kinds of advisory committees that park administrators could use to increase participation. But, basically, performance and openness will probably neutralize much of the pressure for "participation".

A Look Ahead

In a recent address before the National Forest Recreation Association, the Chief of the Forest Service said: "The commercial campground franchise is now a recognized and viable part of camping but so far it has been developed on private land rather than public. Has the time come that development of such commercial campgrounds should be invited on the National Forests?" (McGuire, 1973). Certainly the time has come for a thorough experiment with the concept involving a variety of camping market areas, government built campgrounds, and concessionaire built campgrounds. This is exactly the type of experimentation and innovation which is necessary to reduce the burden on the agency of managing thousands of campgrounds with increasing use levels and a decreasing number of real dollars to do the job.

If, in the mid-1970's, we are asking ourselves whether franchise campgrounds may have a place on public lands, perhaps by the end of this decade we will be truly managing outdoor recreation on a sustained yield basis, charging realistic fees, and returning a percentage of the revenue to maintain the resource. And, perhaps by the mid-1980's we will be asking ourselves whether tax dollars are still needed to subsidize an industry that is self-sustaining and an activity that long ago ceased to be dependent upon a natural environment.

The question of the appropriateness of modern "camping"to our public lands is clearly stated in Curt Fuller's analysis of government-private relations in the camping industry:

> "There is the myth of God's Country. There is the myth of therapy for our souls by communing with Nature. And there is the principle that everyone should have free access . . . But when we examine the myth as far as recreational vehicle camping is concerned, it is quite clear that we are dealing with another situation altogether. We are really not talking about raw nature, primitive living, and God's Country. We are talking about sophisticated self-contained camping vehicles, which are increasing at the rate of 350,000 units annually. We are not talking about a tent beside a mountain stream but about a trailer with a gas furnace controlled by a thermostat, hot and cold running water, a gas refrigerator, a gas stove with oven, and three-way lighting. We are talking about a campground with water and electrical hookups and, if not sewers, a powered honeywagon. We are talking about recreational buildings, swimming pools, organized activities, and luxury facilities generally . . . I question whether it is the government's responsibility to provide such luxury facilities at all, and particularly on a subsidized basis" (Fuller, 1969).

In many instances, there is no question that our public recreation lands can be put to a higher use than parking lots for self-contained vehicles and all of the roads and services that they entail. Just as realistically, the attraction of those public lands demands that some accommodations be provided nearby. Again, Fuller suggests that perhaps the government could acquire a buffer zone outside of the park and, through controlled lease arrangements, allow private enterprise to provide the service facilities.

Commercial outdoor recreation was described in the late 1960's as a "potential giant who is just about to enter the first grade" (Horvath, 1970). If that assessment was correct, the "giant" is now about to enter high school and, in four more years will be demanding his rights. The analogy may be a little imprecise, but we are certainly in for some challenging years in the last half of the 1970's trying to harness the public and private teams to at least pull in the same direction.

LITERATURE CITED

Cleveland, H. 1974. How do you get everybody in on the act and still get some action? Address given at the Annual Meeting of the American Society for Public Administration, mimeo, 7 pages. Syracuse, Univ., Syracuse, NY.

Diamond, H. L. 1970. The private role in the provision of large-scale outdoor recreation, in Elements of Outdoor Recreation Planning. B. Driver (Ed.), pages 171-176. U. Mich.

Downs, A. 1967. Inside Bureaucracy. 292 pages. Little, Brown and Company, Boston.

Drucker, P. F. 1973. Managing the Public Service Institution. The Public Interest, Issue No. 33, Fall, 1973, pages 43-60.

Fuller, C. G. 1969. Private recreation in flux - Needs and Aims. American Forests, August, 1969.

Horvath, J. C. 1970. The role of the private sector in providing recreational opportunities. in Elements of Outdoor Recreation Planning. B. Driver (Ed.), pages 145-169. U. Mich.

Julber, E. 1972. Let's open up our wilderness areas. Readers Digest, May, 1972, pages 125-128.

LaPage, W. F. 1975. Citizen participation in National Forest recreation policy development. Unpub. PhD. Dissertation, 197 pages, State Univ. of NY, Syracuse.

Lloyd, R. D. and Fischer, V. L. 1972. Dispersed versus concentrated recreation as forest policy, in Proc. Seventh World Forestry Congress, Buenos Aires, Argentina.

McGuire, J. R. 1973. Rising recreation needs must be met by both public and private resources. Address given at the National Forest Recreation Association meeting, San Diego, CA., Nov. 14, 1973. 5 pages (mimeo).

Public Land Law Review Commission 1970. One Third of the Nation's Land. A report to the President and Congress by the Public Land Law Review Commission, 343 pages. USGPO.

Ritchie, J. R. and LaBreque, B. and R. J. 1975. Marketing research and public policy: A functional perspective. Journal of Marketing, Vol. 39 (July, 1975), page 12-19.

Sears, D. W. 1975. The recreation voucher system: A proposal. Journal of Leisure Research, Vol. 7, No. 2, pages 141-145.

The Conservation Foundation. 1972. National Parks for the future. An appraisal of the National Parks as they begin their second century in a changing America. 254 pages. The Cons. Found. Wash., DC.

Thompson, V. A. 1965. Modern Organization. 197 pages. Alfred A. Knopf, NY

U. S. House of Representatives. 1974. Small Business Enterprises in outdoor recreation and Tourism. 233 pages. Subcommittee on environmental problems affecting small business of the permanent select committee on small business. 93 Congress. Dec., 1974.

A CRITIQUE OF THE PAPER ENTITLED - "NEW ROLES FOR GOVERNMENT AND INDUSTRIES IN OUTDOOR RECREATION"

James D. Haynes[1]

I received LaPage's paper as promised and made one quick read through. My first thoughts were: "Is the author advocating a policy change for the public parks and recreation agencies or is he only giving food for thought." Without rereading his paper I made three copies and mailed one to three different executive-type guys and requested a brief critique. One went to a Vice President with 30 years experience via Forest Service, lumber companies and paper companies. One went to a forest research analyst with 25 years experience and the other a recreation professional (MA in Recreation) with 15 years experience via state government, real estate, franchise camping, recreation consultant and large corporation. It appears a good many of us get our working life's start with the government. Even I co-oped with TVA during my school years. Without identifying who said what, these are their replies:

1. "The idea that the private sector should provide fee based services is great. Tell him (LaPage) to hang in there. The government can't even run the government."

2. "Sounds like the making of another star-studded B--- S--- seminar on how government can help manage private enterprise.

3. "My reaction is one word - Amen! Such, in my view, provides a proposal for getting the taxpayer out of funding/subsidizing the recreationist. It suggests let the private sector do it and make money out of it if opportunity can be developed and apparently they can, if the author's thesis is valid."

It was obvious the above responses were hurriedly made because the copy was returned to me with those handwritten notes on its face. My thoughts are that these are honest biases, and I concur completely with them. I do believe these type get-togethers have values to both government and the other world.

Further, LaPage's paper was easily read and has good flow. I strongly agree with him, suggesting the public parks and recreation agencies (all) seek new directions toward cooperativeness with the private sectors to free the government from this recreation business. I do see the agencies as innovator - experimenter in the middle ground between resorts and wilderness; mostly, however, as market research in the need/demand area with some prototyping. I also see the middle ground between outdoor resorts and wilderness area as a gold mine of opportunities for private recreation managers to fill those needs and demands.

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[1] James D. Haynes, Forest Recreation Manager, Gulf States Paper Corporation, Tuscaloosa, Alabama. (The Forest Recreation Department is operated as a Business within the Forestry Division. It's assignment is to function separately and maximize the profits for it's parent company using those resources it deems profitable.)

In looking ahead; I believe it is time "Mom and Pop" type concessions as well as the commercial franchisor be encouraged on present public lands (not a purchased buffer zone as suggested by Fuller) provided they return an income to the controlling agency for value received from the resources used. This encouragement should perhaps even include some risk capital.

In conclusion, we strongly believe that the USER and not the TAXPAYER should pay for outdoor recreation. We feel realistic values should be established for recreation products and services no less than the lumberman pays the Forest Service for their timber or the oilman pays the Park Service the royalties due. I personally see no fault with public recreation users returning to the nonusers as well as the user himself a profit in form of lower taxes to fund those public agencies.

I believe LaPage's paper was needed, is timely and hopefully will be heeded. I wish to thank you and Mr. Cordell for inviting me to participate.

COMMENTS

ABSTRACT

SHERIDAN

Comments on the Workshop.--There is NO reason why research and management cannot work together. It can be done officially or unofficially, all that really is required is the desire to.

SELECTED PAPERS PRESENTED AT THE NATIONAL RECREATION RESEARCH APPLICATIONS WORKSHOP, ESTES PARK, COLORADO, 1974

ABSTRACTS

BURY, MCCOOL, AND WENDLING

Research on Off-Road Recreation Vehicles: A Summary of Selected Reports and a Comprehensive Bibliography.--This report summarizes major published research findings concerning recreational use of ORVs. Coverage is restricted primarily to the United States, although literature relating to snowmobiles includes Canadian references. Most included materials have been prepared and released since 1970. But because the rapid growth of ORV usage is so recent, research has progressed minimally beyond identification and description of problems.

CORDELL

The Literature of Planning and Managing Intensively Developed Natural Resource Recreation Sites.--Literature applying to planning and managing developed recreation sites has been classified by type of decision to which it applies, by whether or not it is the result of research, and by degree of applicability. This classification system is intended to assist managers and planners in assessing and applying knowledge contained in the literature. When applied to 130 publications, the classification system revealed that almost 50 percent of the literature deals with maintenance problems and related information. Other areas apparently require additional research attention.

COMMENTS ON THE WORKSHOP

J. A. Sheridan[1]

Someone thought that it might help the group if a different perspective were presented regarding the issues that have been raised. Consequently, I'm the interloper tagged to reflect back to you what I heard here in this meeting. Because my background is a large public utility, a bureaucracy in itself, we've had many of the problems of cooperative effort that you've expressed in your discussions. Having spent 5 years in management at corporate headquarters, I know a little about where of I speak.

In a nutshell, as agent 88 would say, we have here the old research-management-extension service trick. The trick is how do you make it work. Let me see if I can address that from a variety of directions. I'll do this by translating the issues into questions that should be asked and answered if you're to overcome the communications problems that exist.

- Mr. Manager, do you do planning?
- Do you have a long term and short term plan articulated in such a way that others can read and understand it?
- Mr. Manager, why is it that you have urgent needs for short term research?
- What is it about the field manager's job that causes the need for short term research?
- Mr. Manager, are you managing or are you doing other things - such as administration and politicing?

I place no qualitative value judgment on the aspects of management that are related to but not really management. Such things as giving talks at chambers of commerce or Lions, etc. are necessary but not the management of the resource entrusted to you. And finally, Mr. Manager, are you using Research as a PYA, that's a "Protect Your A short three-letter word ending in S" position to cover for high risk decisions that are not research at all, but management perogatives to begin with?

I have a few questions for the scientists also. I don't want anyone to feel left out.

- Mr. Scientist, would you please describe to me that last new theory that you developed?
  If not the last new theory that you developed, how about the last new one that was in your area of speciality?
- Mr. Scientist, what have you personally added to the scientific body of knowledge that has advanced that body of knowledge?
- Mr. Scientist, why can't research be couched in "real time" problems that also add to the development of theory and the advancement of scientific knowledge?

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[1] American Telephone and Telegraph Company, New York, New York.

- Mr. Scientist, how much of your work that you labored over to contribute to mankind has been implemented and is contributing to mankind?
- Mr. Scientist, have you considered taking some courses in public relations?

I could go on to include others such as administrators, extension services and policymakers, but time does not allow. Instead, let me say that the questions I've asked were meant for you to take personally as you see fit. Those same questions I asked in my own company. This recreation group does not have a corner on the market when it comes to problems of cooperative effort.

Let me say that there is NO reason why research and management cannot work together. It can be done officially or unofficially, all that really is required is the desire to.

The Bell System solved some of these problems by making some researchers into managers who could now translate research into action that could be copied by other managers. Other problems are solved by problem solving teams. Teams that can draw on a variety of expertise from anywhere in the company. The concept is called a Matrix Organization and I suggest that this concept could, in a modified form, be of use to the furthering of the quality of outdoor recreation. The Bell System recognizes that scientists and managers are different. They also have to be appraised differently. I personally believe that most scientists would like to see their work employed and that is indeed part of their reward system; they also like to eat. We pay ours well, but most are expected to work on the company's problems, not esoterics. To that end, there are research review teams that have field managers as part of the team. There is generally some time allowed for personal interest research, in your language that would be basic or pure research. There are many existing mechanisms in industry that would lessen your communications problem. I suggest you appoint a working group to investigate those techniques actually used in industry to overcome similar problems.

As someone said earlier in the meeting, "You would be had for lunch," if you were in a competitive situation.

It has been a real pleasure for me to attend your meeting and I want to thank Stu Davey and Neil Stout for suggesting that I attend. And Ken Cordell who graciously extended the invitation. I know it is difficult to invite an outsider into your midst to hear some of your most private concerns. I thank you for that opportunity.

RESEARCH ON OFF-ROAD RECREATION VEHICLES:
A SUMMARY OF SELECTED REPORTS AND A COMPREHENSIVE BIBLIOGRAPHY

Richard L. Bury, Stephen F. McCool, and Robert C. Wendling[1]

Abstract.--This report summarizes major published research findings concerning recreational use of ORVs. Coverage is restricted primarily to the United States, although literature relating to snowmobiles includes Canadian references. Most included materials have been prepared and released since 1970. But because the rapid growth of ORV usage is so recent, research has progressed minimally beyond identification and description of problems.

INTRODUCTION

Off-road vehicles (ORVs) have become a pervasive factor in the use and management of rural lands since the late 1960's. Conflicts between ORV users and non-users have occurred both on private lands, and on public lands where both groups are equally entitled to enjoy benefits of the resources.

The ORV phenomenon, as seen throughout this report, is an extremely diverse one. It consists of a complex interaction among (1) people's attitudes, preferences, and behavior; (2) environmental factors such as land use, and effects of ORV traffic on soils, vegetation, and animals; and (3) machine-related aspects such as vehicle type, engine size, and type of tires. Within the framework of this reocgnized complexity, the manager must seek optimal solutions through maximizing advantages and minimizing disadvantages associated with providing and maintaining ORV recreation opportunities.

Research can provide basic support information required for such optimization of ORV management.

This report therefore seeks to summarize major published research findings concerning recreational use of ORVs. Readers interested in current, unreported research are advised to search through computerized systems such as the Smithsonian Science Information Exchange and the Current Research Information Service (U. S. Department of Agriculture).

Coverage is restricted primarily to the United States, although literature relating to snowmobiles includes Canadian references. In addition, coverage has been expanded beyond formal research efforts to include selected basic information and concepts from administrative reports and technical articles.

Most included materials have been prepared and released since 1970. Because all materials are so recent, in-text citations do not indicate year of publication except as necessary to distinguish between items attributed to the same author.

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Because the rapid growth of ORV usage is so recent, research has progressed minimally beyond identification and description of problems. Further, most ORV research relates to snowmobiles, and is a direct response to the exceedingly rapid growth in usage of that machine.

Several individuals have led in identifying and defining management issues and in providing research information currently available on ORVs; among these have been Baldwin and Stoddard, Lodico, the U. S. Department of the Interior's Task Force on Off-Road Vehicles, McCool and Roggenbuck, and speakers at the 1971 and 1973 Symposia on Snowmobiles and Off The Road Vehicles held at Michigan State University and edited respectively by Chubb and Holecek.

An in-depth bibliography is provided; in it are cited many documents not discussed in the text. A table helps the reader find all items in the bibliography that are relevant for each of the twenty-eight subject areas presented in the text. The bibliography itself represents a detailed search of (1) relevant printed indexes; (2) the excellent bibliography on ORVs available from Lime and Leatherberry; and (3) computer searches within the data bases of the National Technical Information Service (NTIS), Psychological Abstracts, Social Sciences Citation Index, and the Cataloging and Information system (CAIN) of the U. S. Agricultural Library.

ECONOMIC ASPECTS

Numbers of ORVs: Production, Sales, Vehicles in Use, and Projections

The below excellent summary and prediction for numbers and sales was prepared by Stupay in 1971 (p. 15-17):

> With rising income, favorable age mix changes, and growing suburbanization and leisure, recreational vehicle usage will continue to rise. Total recreational vehicle sales are expected to rise by over 3.5 percent annually from 1.8 million units to 2.5 million units annually by 1980. The various vehicle markets are reaching a high level of penetration and there does not appear to be a new major vehicle such as the motorcycle or snowmobile to continue the 1960's explosive growth . . .
>
> Motorcycles and mini-bikes and cycles are expected to lead in growth and in usage. In 1970, some 730,000 motorcycles and nearly as many minicycles were sold. Sales are expected to lift to 850,000 units by 1980, with registration rising from 2.7 million in 1970 to some 5 million in 1980 . . .
>
> The snowmobile achieved phenomenal growth in the 1960's . . . shipments rose rapidly to 190,000 units in average 1966/68 and to more than 500,000 units in 1969 and in 1970. United States sales peaked at 317,000 in 1969.
>
> Snowmobile sales will continue to grow but at a sharply reduced rate . . .

Although Stupay's predictions seem carefully made, three major occurrences since 1971 may produce experience considerably at variance from his predictions. First, the predictions rest on assumptions of participation rates which may change in ways different than predicted. Secondly, the petroleum supply and cost situation may depress purchases and use; and lastly, America's economic condition of simultaneous economic stagnation and inflation ("stagflation") may well induce consumers to purchase fewer ORVs and to use their current ORVs less than predicted.

As of 1973, American and Canadian snowmobile owners possessed an average of 1.8 snowmobiles, and had owned in total an average of 2.9 snowmobiles since the machines became available. Also, 63 percent of the total respondents in the Winona survey of 1973 indicated that they planned to buy a snowmobile within the next two years (p. 1,15).

Writing in early 1975, Doyle indicated that the snowmobile market was stabilizing to an expected sales level of 250,000 units per year; producers had shrunk from more than 100 firms to as few as ten firms producing more than 500 units (p. 12). The industry hoped to expand sales through the next few years by developing safer and quieter machines, and by encouraging development of more snowmobile trails and riding areas (p. 13).

Motorcycle numbers and sales are more difficult to obtain; the below figures are worldwide:

> Sales of motorcycles increased from approximately 60,000 in 1960 to

> 1,430,000 in 1970. The industry expects to reach annual sales of 1,700,000 units by 1980. The motorcycle figures above do not include minibikes, of which nearly 700,000 were sold in 1970. Estimates of total off-road use are further complicated because nearly half of the vehicles registered for road use possess some off-road capability. An estimated 30 percent of these are occasionally used off the road [in the United States]. (Baldwin and Stoddard, p. 5,6)

Much less information is available for dune buggies and all-terrain vehicles (ATVs). As of 1973, the Department of the Interior estimated that 200,000 dune buggies were in use in the U.S.; manufacture and sale of these ORVs was growing rapidly at that time (Baldwin and Stoddard, p. 6).

Economic Impacts and Trade-Offs

> The economic impacts of ORVs during any given year will depend on factors such as weather, seasonality, general level of regional and national economy, price of machines, numbers sold, fees which may be paid, and servicing costs . . . (Michalson)

To the economist, economic impact studies require a rigorous methodology such as that presented in Michalson's paper, "A Methodology for Determining the Economic Implications of Off-Road Vehicles." Most of the studies reported were considerably less rigorous than Michalson, and thus should be regarded as first approximations only.

Total expenditures related to snowmobiling during the 1973/1974 season in Michigan/Wisconsin / Minnesota were estimated to be $506 million. This included $396 million capital expenditures, $37 million repairs, $7 million registration fees, and $7 million collected in gasoline taxes (Gogebic c. 1974).

During the 1974/1975 season in New York, snowmobilers spent $84 million on snowmobile-related purchases and activities; in addition, the State treasury received $4-3/4 million from registration fees, gas taxes, and sales taxes (ISIA 1975, p. 1).

The size of the snowmobile-related industry in 1972 is illustrated by the following:

> Counting allied equipment fields and service functions, the annual sales of the industry surpass $1 billion. Almost 100,000 people in the U.S. and Canada are directly employed by the industry, utilizing over $1 billion in capital investments . . . Case studies of the impact of the snowmobile industry have been prepared for several states. Minnesota represents a special case--over thirty percent (30%) of all snowmobiles produced in North America are made in this state. Direct industry employment in the state exceeds 19,500 people, with a combined personal income in excess of $126.6 million (Doyle 1974 c., p. 9).

Effects on Resource Owners and Managers

Profitability of areas for ORV use has received little attention by researchers. However, a study of eight snowmobile areas in central New York (Moeller) revealed that successful operations should usually contain 300 acres or more, half of which should be wooded, be located "within a 1-hour driving radius of at least

100,000 people," and "be situated in a region of heavy snowfall . . . Several operators felt that a 10 week season, with a minimum continuous snow cover of 4 inches, would be required to break even on their investments." (p. 7,9) Rental fees for snowmobiles, under the competitive conditions of 1970-1971, were insufficient to produce profitable enterprises; operators felt that profitability could not be assured without supplemental enterprises such as fuel, repair parts, accessories, and maintenance (p. 11).

Average development cost for snowmobile trails has been reported to range from zero to $300 per mile. The Hoosier National Forest in southern Indiana expects to spend $1,000 per mile for double-track ORV trails and $500 per mile for single-track trail (U. S. Forest Service, Hoosier National Forest, p. 34).

Operation costs for snowmobile trails also showed considerable variation, ranging from $50 to $210 per mile per season (Keenan, p. 216; Hetherington 1971b, p. 148; Armstrong, p. 171-172). Yellowstone National Park expended $45,000 grooming 208 miles of snowmobile trail in 1972; this calculated to an average cost of $210 per mile for the season (Armstrong, p. 171-172).

Comparable studies for other types of ORVs were not discovered.

Effects on ORV Operators and Owners

During the 1973-1974 season in Minnesota/Michigan/Wisconsin, the average snowmobiler spent $367 on equipment (Gogebic 1974, p. 62).

The average cost of a snowmobile in this three-state area circa 1970 was $903 (Potter, p. 65). Ontario snowmobilers invested an average of $1,200 per owne during the 1965-1970 period in snowmobiles and related equipment; these expenditures were about 84% for the basic machine, and 10% for special clothing. The estimated expenditure on snowmobiles and related items during this 5-year period was $120 million (Ontario, p. 34-36).

The owners' average expenditure per day of machine operation was $18.20 in the above three-state area during 1973/1974 season (Gogebic c. 1974). Details from this same study reported the following averages of 12-month seasonal expenditures: $45 repairs, $52 snowmobile gas and oil; $25 insurance; $56 general trip expenses when snowmobile was trailered, and $69 general trip expenses when snowmobile was not trailered (Gogebic 1974, p. 63-65).

In combining both investment and usage costs, the average yearly expenditures related to snowmobiles during the 1973/1974 season in the above three-state area was $543 per machine (Gogebic c. 1974).

Again, comparable information for other ORVs was not found.

Effects of Petroleum Shortages and Stagnation/Inflation

Within the combined states of Minnesota/Michigan/Wisconsin during the winter of 1973/1974, the petroleum shortage apparently induced a reduction of 5,689,000 user days of snowmobiling (Gogebic 1974, p. 3,53); this was a 28 percent reduction as compared with the previous season.

Snowmobile sales were depressed during the period of November/December 1973 when the petroleum shortage first became severe. The industry estimates that 30,000 units were not sold as a direct fear of energy shortage (Doyle 1974a, p. 11).

BEHAVIORAL ASPECTS

It appears that many or most managerial techniques need to deal with people and their actions, rather than with the impact of ORVs on the environment. For example:

> " . . . some of man's basic rights are involved in the off-road vehicle issue--conflicts such as the rights of the individual versus the state, individual property rights versus common public rights, and economic growth versus the quality of life." (Dunn 1971, p. 165)

> "Public concern as discussed here reflects conflicts of interest, an invasion of privacy, and direct interference by snowmobiles with other winter sports activities in the same geographic area . . ." (Griffith, p. 5)

Social Demographics

Many research reports have described the social demographic characteristics of ORV users. Individual ORV users were found to be at least as varied as the machines. In spite of this, drivers of all ORV types showed a great tendency to form clubs.

A comprehensive survey of snowmobile owners in North America yielded these findings: 66 percent of the households surveyed owned two or more snowmobiles; average age of the owner was 38 years; 86 percent were married; households averaged 4.2 persons; 70 percent had an annual income greater than $10,000 dollars; 65 percent were non-urban (i.e., from a town of less than 25,000 population or residing not within 20 miles of a city of 100,000 population). Occupation ranged as follows: 21 percent were craftsmen/foremen, 15 percent were managers/proprietors, 15 percent were operators, 11 percent were farmers/farm managers, 11 percent were professional/technical, and 25 percent were classified as other (Holecek, p. 55).

Plumb (p. 132) characterized the dune buggy and 4-wheel drive owner who utilized Back Bay National Wildlife Refuge as 28 years of age, male, married with two children, two years of college, and a manager or administrator with an annual income of $10,000 to $20,000.

Peine (p. 32-34) found conflicting results in his study of the Tucson Jeep Club and Tucson Sandbuggy Association. In comparing the two clubs, results indicated that members of the jeep club had higher average incomes, educational levels, and more were white collar workers. However, average age (34 years) and average family size (four) were very similar for both clubs.

Values and Attitudes

Several recent studies have begun to reveal the values held by ORV enthusiasts, and the motivations underlying their behavior. Peine (1972) found that ORV users have orientations toward the land, the machine, and the activity. McCool (1974) hypothesized orientations toward the land, the machine, and the activity. McCool (1974) hypothesized orientations toward the machine, the environment, and other people.

Bury and Fillmore (p. 34-36) found that most campers regarded cyclists as self-centered, anti-social, inconsiderate of the rights and feelings of others, highly motivated, and unintellectual. In comparison, riders saw themselves as socially accepted, highly motivated, and considerate of the feelings of others; they rated themselves lowest in the intellectual dimension.

Roggenbuck and McCool (p. 12,13) best summarized land use conflicts in comparing land managers with ORV users. The former have traditionally been trained in the natural sciences--with concepts of sustained yield, multiple use, and preservation. ORV use is not compatible with their naturalistic value system. The ORV user, on the other hand, does not have a naturalistic value system and views the ORV as an appropriate means of enjoying the recreational opportunities of public lands.

Knopp and Tyger (p. 14,15) reported that snowmobilers and ski-tourers possessed statistically significant conflicting attitudes on various recreation land management issues. Basically, snowmobilers felt managers should place fewer restrictions on recreational uses of land, while the ski-tourers recognized a need for occasional restrictions.

Expectations and Preferences

While few attempts have been made to assess ORV users' expectations, several early snowmobile surveys revealed interesting patterns of activity preferences. For example, Gogebic Community College (1974, p. 73-90) conducted an extensive survey of snowmobiler preferences and opinions in Michigan, Minnesota and Wisconsin; see also Ontario Department of Tourism, Lindsay, Kuehn, Kopischke, Bury and Fillmore, and Johnson *et al*. Details of findings are too voluminous for description here. However, we may draw upon these studies for general guidelines if we are willing to assume that preferences are idealized expectations.

The Forest Service's Environmental Impact Statement on ORVs (USDA Forest Service, p. 10-13) also deals with user expectations and preferences. A review of public responses identified four main issues of specific interest to the public. They were (1) alternatives for implementation of ORV regulations, (2) designation of areas, (3) the time frame to complete the designation, and (4) the exemption of ORVs used in mining pursuits from regulations governing all other ORV use.

Characteristics of Use

Several studies provide detailed information on characteristics of ORV usage. For example, the Ontario Department of Tourism study of snowmobilers revealed that the most common frequency of use (median) was between 21 and 40 days per season; the overall average (arithmetic mean) was 41.9 days. This usage was distributed almost equally between weekend days and weekdays; the average duration was 3.7 hours per day. Over half of the respondents stated that more than one-fourth of their snowmobiling occurred at night.

In contrast, a survey of Michigan snowmobilers (Michigan Department of Natural

Resources et al., p. 30-40,46) revealed an average of 24.6 days of snowmobiling per season; the average after-dark snowmobiling was 13.0 days. Respondents spent an average of 14.7 days on their own property or that belonging to relatives or friends, 7.8 days on state or national Forest lands, 1.5 days on corporate land, 1.2 days on metro and city parks, golf courses, school property, etc., 0.4 day on state park and recreation areas, and 0.4 day outside of Michigan. This distribution was, of course, affected by the location and relative abundance of lands, and managerial actions relative to snowmobiling on the various land ownership classes.

A survey of operators of dune buggies, trail-bikes, and minibikes found that the four most popular activities were informal competition, hill climbing, camping, and sightseeing (Johnson et al., p. 4,5). The average operating time was five hours per day, with minibikes averaging 3.2 hours and dune buggies averaging 6.6 hours. Members of the average respondents' household spent two weekends per month at a use area, with an average of 1.9 Saturdays and 2.1 Sundays. Most of these ORV users operated their machine with family and friends, while considerably fewer operated alone or with organized clubs.

Peine's comparison of the Tucson Jeep Club and Tucson Sandbuggy Association indicated that sightseeing and exploring were the most popular activities of all ORV owners interviewed (p. 32,33). Most travel was to, and within, established recreation areas; very little was cross-country. The typical trip of both clubs consisted of one-day sightseeing, a picnic lunch, and a travel distance of less than 100 miles.

Activity Aggregation

Use of ORV's is generally associated with other identifiable recreational activities. In many instances, a specific set of activities (activity aggregation) is associated with a given ORV activity. For example, Dahms (p. 15) found in a nation-wide survey of trail-bike and motorcycle users that the most popular single hobby (after motorcycling) was hunting and fishing, followed by camping. Though figures on participation in hunting and fishing were not provided, 79 percent of the respondents camped when they rode.

At Land Between the Lakes in western Kentucky, Chilman and Kupcikevicius (p. 7) found swimming to be the most popular accessory activity of trail-bike riders, with 48 percent of the riders participating; camping followed with 44 percent, and picnicking with 38 percent.

In a study by Holecek (p. 56), 72 percent of the snowmobile riders had fishing licenses, 77 percent had hunting licenses, 18 percent had 4-wheel drive vehicles, and 50 percent had boats.

Conflicts Among Users

Conflicts among recreational users and non-users of ORVs have been identified as one of the ten most important questions related to ORVs in the West (Mc Cool and Roggenbuck; v. 1, p. 22,23).

Conflicts between ORV users and non-users may be grounded in noise, knowledge of the machine's presence (or having been present), fear of personal harm, and physical impacts on the environment (Butler, p. 9).

Lindsay (p. 7-25) surveyed the extent and cause of outdoor recreation conflicts in Vermont. Results of particular interest were that: (1) snowmobilers and homeowners were the two groups most often in conflict; (2) conflicts most commonly occurred at night in urban and suburban residential communities; (3) groups creating the greatest amount of conflict were those requiring fairly larg land or water areas for their activity, those using private land, and those without designated areas for their sport; and (4) the causes of conflict included discourtesy, litter, noise, safety, trespass, vandalism, and competition for space.

In a study by Bury and Fillmore (p. 32,33), campers were asked to name and rank the three main disadvantages of having a motorcycle area near a campground. Noise led all the rest by a wide margin. However, their answers may well have represented biases rather than experience.

Many ORV operators use their machines on hunting, fishing, and camping trips (Fluharty; p. 17; Chilman and Kupcikevicius, p. 7); this clearly points to possible conflict situations. For instance, Malaher (p. 431) suggests that conflicts could arise from snowmobilers disturbing wildlife being hunted by others on foot.

A major problem in the east has been the operation of ORVs on private lands without prior consent of the landowner. In the west, conflicts with the traditional consumptive uses of land-based resources have occurred. For example, Fluharty (p. 13,14) cited a Bureau of Land Management report which described soil compaction and destruction of range vegetation. These impacts lead to a reduction in productivity of the range for beef. Additionally, range fires have been started by motorcyclists, and some ranchers even describe their cattle being chased by motorcycles.

Depreciative Behavior

These human acts reduce or destroy the resource and facilities, or interfere with the experience of other recreational participants. Although depreciative behavior among ORV participants was frequently the subject of resource manager reports and informal discussions, scientists have not yet specifically focused on the depreciative behavior of ORV participants.

The array of potential depreciative behavior forms is broad: vandalism, theft, trespass, rule violations, and destruction of archaeological sites. For example, Baldwin and Stoddard discuss the increasing frequency of thefts and vandalism during the winter at properties largely inaccessible before the snowmobile.

Motivations for depreciative acts in other recreational environments have been typologized as entertainment, convenience, disregard, ignorance, and interference with personal goals (Clark, Hendee, and Campbell, 1971). Whether this typology will apply also to ORV operators is a question needing considerable research.

Perception of Images

Snowmobilers in a two-county area of New York were questioned about their awareness of snowmobile effects on wildlife and damage to vegetation (Hill 1971,

p. 6,7,15). Only 7 percent of the respondents reported observing damage to wildlife; the foremost incident was intentional harassment of animals. Thirty-seven percent of the respondents reported benefits such as use of snowmobile tracks by deer, snowmobilers carrying food to wildlife, and rescue of deer chased by dogs. Hill also noted that 28 percent of the respondents reported substantial vegetative damage by snowmobiles; seedling and shrub damage was most frequent.

Peine's (1969, p. 33) investigation of Tucson Jeep Club and Tucson Sand Buggy Association members indicated that the clubs were aware of rising public concern for deterioration of the countryside caused by ORVs. In fact, they were so concerned that they carried out conscientious programs to minimize damage to areas they visited.

SAFETY ASPECTS

Noise

The level, duration and physical frequency (wave-length) of noise may have extensive impacts on the health and safety of ORV operators and spectators.

Most studies related to health and safety aspects of ORV noise have investigated temporary shifts of hearing thresholds and ringing ears (tinnitus). Bess (1971, p. 154-155) reported a high probability of hearing damage following exposure to only 30 minutes of full throttle snowmobile operations.

Following exposure to snowmobile operation, one-third of the males and one-fourth of the females in a study reported ringing in the ears, and about 18 percent experienced temporary changes in hearing (Stahl and Bess, p. 9). The results of another study (Bess and Poynor, p. 166) strongly suggested that continued operation of snowmobiles will result in significant hearing damage.

While the authors have found only limited experimentation concerning motorcycle noise and hearing damage, several investigators (Bess 1973, p. 7; Harrison 1973, p. 27) have reported that helmets do not provide adequate hearing protection, especially at speeds below 45 m.p.h.

Deaths and Injuries

Several authors (Fleming 1969; Fleming, 1974, Vila and Klopchic, and Mc Lay) have reported on accidents associated with snowmobile use. One study of snowmobile accidents found the collision rate five times that of other motor vehicles and the death rate six times as great (Vila and Klopchic, p. 37). Factors which appear to contribute most to snowmobile-associated injuries are jumping the vehicle, lack of experience, poor visibility, speed, alcohol, barbed wire, climbing over banks, equipment not in repair, and thin ice (McLay). Exposure and hypothermia are also contributing factors (Rand, 1969).

The safety and health hazards associated with other types of ORVs have been extensively discussed before (Bureau of Transportation Safety; National Motor Vehicle Safety Advisory Council). Both reviews suggest a strong need for systematic data collection to determine causes of accidents, and detailed study of collisions, in order to devise and implement safer equipment, facilities, and operational regulations.

Safety Equipment

Daytime use of motorcycle headlights significantly reduced the accident rate of motorcyclists in states requiring such operation (Janoff et al.). Further, use of a helmet significantly reduced casualties occurring in motorcycle accidents (Allsop 1967; Lunenfeld and Varady 1970, and Richardson 1974).

The following items appear necessary for safe operation of snowmobiles: dead man's throttle, roll-bar, crash helmets, goggles, and protective clothing (Percy).

TECHNOLOGICAL ASPECTS

Noise

Many conflicts with other recreational activities originate with noise. In the last few years, technological advances by manufacturers have reduced noise production, and most states now have standards establishing the maximum permissible noise generated from ORVs (International Snowmobile Industry Association, 1974b). Noise will probably continue as a difficult managerial problem--and especially so as more persons visit recreation areas, and ORV noise therefore affects more non-ORV users (Lindsay).

Noise generation from snowmobiles and motorcycles has received considerable attention in the literature. Central to an understanding of the noise issue is the concept of "vanishing distance"--the distance under which ORV-generated noise becomes inaudible above the always-present "background noise." Vanishing distance depends on the amount and physical frequency (wave-length) of noise generated at the source, and intervening vegetational/topographic/atmospheric conditions.

Researchers report somewhat contradictory results of vanishing distance across similar vegetational types (Harrison, 1974d). The Motorcycle Industry Council (1973) indicated that the vanishing distance within a wooded area varied from 1600 feet for a 76 dB source to 12,800 feet for a 90 dB source. Operation of two or more ORVs will apparently increase the total noise generated only slightly (Harrison 1974d, p. 7).

The variation in noise generation by ORVs is great. Harrison (1974b) tested 10 different motorcycle models in a drive-by procedure and found a range of 74 dB-93 dB, measured at 50 feet on the A scale; vanishing distances varied from 1400-3900 feet. Noise tests of 15 different models of 1969-1972 snowmobile ranged from 77 dB-99dB (Harrison 1973c). In general, he found that the older the model, the greater the noise generation.

Both the American Motorcycle Association (AMA) and the International Snowmobile Industry Association (ISIA) have responded to the noise issue by developing programs and vehicle changes to reduce noise generations (AMA n.d.; Doyle 1974a; Doyle 1974b). Additionally, the Noise Control Act of 1972 (U. S.

Congress 1972a) gives the Environmental Protection Agency authority to develop and implement standards for maximum noise levels produced by recreational vehicles.

Exhaust Emissions

Extensive programs of exhaust testing and monitoring are continually conducted by the Environmental Protection Agency and various manufacturers.

The total impact of lead contamination on a community water supply is probably variable depending on the intensity of the snowmobile use. Heaviest concentrations of lead were found at 1-1/2 feet from the midpoint of the snowmobile track (Ferrin and Coltharp, 1974).

Because many types of ORVs could cause wildfire, requirements and standards have been established on both state and federal levels for the use of spark arrestors (U. S. Department of Agriculture).

Resource and Facility Needs

In a California study of owners of mini-bikes, dune buggies, cycles, four-wheel drive, all-terrain vehicles, and other ORVs, 68 percent of the 1,210 respondents strongly agreed that most public lands should be available for some form of ORV use (Johnson et al., p. 5). The most common demand expressed in comments found on 688 of the returned questionnaires was "Give us more land." Other comments frequently expressed dealt with expressions of preference for large and relatively unregulated areas, recommendations for one-way riding trails, separation of two-wheeled vehicle use areas from four-wheeled vehicle use areas, special juvenile operating areas convenient to cities, and requests for information on legal riding areas throughout the state.

Hetherington (p. 76) stated that snowmobile resources and facilities should include a minimum snow depth of three inches; varied topography; adequate parking; snack bars and restaurants; and trails with points of scenic or historical interest, scenic outlooks, trails connecting towns, and/or designed for multiple use (e.g., snowmobiling, trail-bike riding, horseback riding, skiing, and snowshoeing), systems with spider-web design including loops at 1, 5, 10, 25, and 50 miles, and a sign system and posted maps along the trail. In contrast, Vila and Klopchic (p. 34) found that Ontario snowmobilers preferred "unorganized, open lands, bush and wooded areas in a hilly landscape with no special facilities except snowmobiling trails." Respondents further indicated little interest in organized areas with facilities.

Design Standards for Trails

Existing standards appear to consider management objectives with respect to type of ORV and type of experience desired, reduction of conflicts with other wildland uses, safety, minimization of environmental impacts, and amount of expected use.

The U. S. Forest Service (1974) has developed recommended trail design standards for both one-and two-track ORV trails. Bury and Fillmore (1974), from their field study of trail-bike riders, suggested one-way trails, maximum trail width of six feet, maximizing the number of jumps, and varying the radii on turns (p. 41-44).

ENVIRONMENTAL ASPECTS

Research indicated some distinctly different environmental impacts from snowmobiles than from other ORVs. For example, soils are affected little by snowmobiles (Pendleton et al., p. 2,5; Walejko et al. 1972 and 1973), but are substantially affected by other ORVs (Davidson and Fox, p. 388-389).

The best bibliographic study of environmental impacts to date is the literature review by Lodico in 1973 for the U. S. Department of the Interior. In the interest of avoiding duplication, most of her extensive text findings will not be referenced herein. Other major compilations are in Baldwin and Stoddard (especially pages 8-33) and in Proceedings of the 1971 and 1973 Symposia on Snowmobile and Off-Road Vehicle Research edited respectively by Chubb and Holecek.

Systematic investigation and experimentation concerning impacts must acknowledge the influence of various types of ORVs, operating conditions, soils and plant and animal communities. The combinations (and therefore, complexity) of environmental and technological variables are vast; therefore, virtually any study conducted on this topic will lack generalizability. For example, a 250cc motorcycle driven over a sandy soil 25 times in one week in a semi-arid climate will have quantifiable impacts. But, impacts may be markedly different if the soil is finer texture.

Effects on Vegetation

Snowmobiles were shown to produce considerable vegetative damage above the snow (Wanek 1974, p. 150; Wanek 1971a, p. 127; Wanek 1971 b; Wanek 1973a, p. 38; Meitz, p. 80). In contrast, damage below the snow depended on depth of snow and intensity of snowmobile use. Compaction by snowmobiles produced lower ground temperatures and retarded the growth and reproductive success of early spring flowers (Wanek, all references).

Woody plants were found more vulnerable to mechanical damage than herbaceous ones (Wanek 1974, p. 21); this could be advantageous in powerline rights-of-way and other locations where managers wish to discourage woody vegetation, and argues for use of such rights-of-way as snowmobile trails (Wanek 1973, p. 38).

Response of alfalfa to snowmobile traffic was also tested at four locations within Wisconsin by Walejko et al. Damage appeared related to snow depth and type, and was directly attributable to the temperature and/or smothering effects from "compacted snow or ice sheets which occur on trails in certain types of snow." (Pendleton 1972, p. 6) These results were obtained on 3-year-old, well-established stands. Alfalfa under fairly deep snow showed no reduction in yield during the following year; under thin snow, yields were reduced as much as 30 percent (Walejko et al. 1973, p. 273).

Bluegrass, brome grass and other such forage grasses appear very resistant to damage by snowmobiles (Walejko et al., 1972, p. 166). In the Wisconsin study cited above, "Heavy snowmobile traffic imposed on established bluegrass areas resulted in no reduction in yield but stands did recover at a slower rate in early growth and vigor. Late bluegrass harvests during the summer were similar in response to early harvests." (Walejko et al. 1973, p. 166)

The impact of snowmobiles on young hardwoods and conifers in New York was greater on slopes than on the level, due to the churning action of the snowmobile belt (Meitz). The study indicates considerable variance in results, details of which will not be reported here.

Off-road motorcycling in the Mojave desert appeared to increase the representation of some vegetative species; of course, the representation of most species decreased (Davidson and Fox, p. 389). In a carefully-documented article on ORV effects upon the California desert, Stebbins found that:

> The overall effect of ORVs on desert vegetation is to reduce the variety of native species and the size of their populations. In areas of heavy use they completely denude the landscape, and recovery is expected to require many decades, if it occurs at all. (Stebbins 1973b, p. 296).
>
> Unfortunately, ORVs are often attracted to those very parts of the desert where the flora (and associated fauna) is likely to be most varied and where novelties are most likely to occur--near water; in regions of topographically varied terrain; and in the vicinity of dunes. (Stebbins 1973b, p. 295)

Effects on Animals

Snowmobiles created little effect on larger animals and mixed, moderate effects on medium-sized animals; small animals overwintering in subsnow environments were drastically affected.

Large animals. Most research concerning large animals has been tied to the effects of noise and movement of snowmobiles in creating disturbances of the animals. Deer did not significantly increase or decrease their home ranges during three weekends of snowmobiling, nor did their rate of travel increase under conditions of snowmobiling (Bollinger et al., p. 4, 25-30). The results indicated that . . . "under the conditions of this study, snowmobiles have to be within sight of the deer before the animal will react by moving away." (p. 6)

Therefore, this study failed to support the allegation that deer increase their movement and thus become physically stressed in response to snowmobile traffic generating 45 to 65 dBA at the point of deer reception. This conclusion was reached with as many as 31 snowmobiles in operation on the test area during a 4-1/2 hour period. The research also revealed that deer will change home ranges markedly even if snowmobiles are not present.

A somewhat parallel study on white-tailed deer was conducted by Dorrance et al. in northern and central Minnesota during the 1973-1974 winter. Results were not in all cases supportive of the Bollinger et al. study. As in the Bollinger findings, Dorrance discovered that light snowmobile traffic displaced deer from areas immediately adjacent to the snowmobile trails, but that further snowmobile traffic had little effect on deer movement (p. 1,2).

Elk appear more sensitive than deer to the sight and sound of snowmobiles (U. S. D. I. Bureau of Land Management, Utah State Office, p. 1,2). The Bureau of Land Management (BLM) study indicated that only a few snowmobiles would caus an entire elk herd to move away from the machines; this finding is parallel to that of the Bollinger, Huff, and Dorrance studies related to deer.

Medium sized animals. Animals of intermediate size exhibited no general responses to snowmobiles. Snowshoe hares avoided snowmobile trails, for example, but red foxes were more active near and in such trails (Neumann and Merria p. 211).

Another study discovered that red, grey and fox squirrel activity was appa ently no different in the area of snowshoe trails than snowmobile trails (Huff *et al*., p. 28). This same Minnesota study indicated that red fox used snowmobile trails less than snowshoe trails (p. 28). It was also discovered that:

> The number of mammal tracks crossing the snowshoe transects was significantly greater than the number crossing snowmobile trails for six of the nine weeks . . . mammals used snowmobile trails more during times of deep snow or drifting, and when traffic on the snowmobile trail was lowest. (p. 27,28)

The effects on animal populations of humans equipped with ORVs appears to be mixed geographically and with relation to particular species. (Doherty, p. 63; Usher, p. 178-179).

Small animals. Snowmobiles may cause the ill health and death of small animals using the air space (subnivean layer) between snow and the ground surface; this effect occurs through snow compaction by snowmobiles, and its resultant mechanical barrier to the movement of small animals and reduction of the temperature-insulating qualities of snow (Schmid 1971b, p. 107).

The reduction in population of these small mammals could well reduce the population of species preying upon them--hawks, owls, foxes, etc. (Brander) p. 33).

Effects on fish. Accelerated harvesting appears to be the main concern related to impacts of ORVs. The most striking documentation concerned easier access to remote lakes provided via snowmobiles in the wintertime. One report indicated that 556 pounds of fish were harvested from a remote lake on a single day; this would have been an entire season's catch if snowmobile access had not been possible (Cooney and Preston, p. 19). However, the snowmobile has proven advantageous in dispersing fishing pressures on the larger lakes, rather than concentrating fishing near road access points (Doherty, p. 63).

Effects on desert animals. Only a few studies, preliminary at best, were found relating ORV operations to desert animals. The ecology of Dove Springs within the California Desert was studied during a ten year period and changes noted in response to increasingly high use by ORVs (Berry). The tortoise apparently disappeared; the density and diversity of populations of small mammal and lizards was reduced.

Effects on Soil

Snowmobiles produced little mechanical effect on soils (Pendleton *et al*.,

p. 2,5; Walejko et al. 1972 and 1973).

Soil temperatures during the winter were significantly reduced in the soils immediately underlying snowmobile trails. The temperature differential between soils under undisturbed snow and those under the snowmobile track were in the order of 5° to 9°C (Wanek 1972, p. 3,7). These effects are different within different soil types. At six inches below the surface of fields with three-year old alfalfa stands, the temperature within sandy soils was found to be 2-5°C colder than within clay loam soils on the same days (Wanek 1974, p. 12). In contrast, the temperature responses of bog soils to various degrees of snowmobiling was quite small, being on the order of less than 3°C (Wanek 1974, p. 12).

Soil disturbance by wheeled vehicles is abundantly evident in desert situations (U. S. D. I. Bureau of Land Management, California State Office, 1970b). One such exploratory study was conducted by Davidson and Fox on relatively coarse soils in the Mojave Desert. Although the amount of motorcycle use intensity was not recorded, such use produced some compaction at the surface. Solid bulk density had increased very little, but seemed critical in that infiltration capacity was greatly reduced (Davidson and Fox, p. 388-389). In contrast, Berry found that heavy pounding by ORVs could increase the density of desert soils markedly to a depth of at least three feet; this different finding could be due to differences in soils, use intensities, soil moisture conditions, types of ORV use, and/or methods of soil density measurement.

Within Arctic environments, off-road vehicular traffic is very common. Investigators believe that impacts on soils may be potentially very serious, especially on permafrost terrain (Rickard and Brown, p. 61). Because of fragile soils and short growing seasons, the recovery of ORV tracks has been very slow. Wet and marshy terrain showed more effects than well-drained sites (Rickard and Brown, p. 55).

Effects on Water Quality and Quantity

Snowmobiles appeared to increase the water content of snow in compacted areas, especially in locations where evaporation from snow normally exceeds infiltration (Hogan). Tests also showed that compaction increased snow cover retention. It was alleged that steep and unvegetated roads would thus be protected until after the period of maximum snow runoff had passed. This conclusion was supported by research of Soil Conservation Service snow surveyors, who also suggested that "a systematic contouring of a critical watershed with snow machines offers the potential of actually 'farming' the snowpack for valuable water supplies." (Work and Pearson, p. 35). Thus it appears that snowmobile action within watersheds may benefit water quality through decreased water turbidity, and improve water quantity through lessening losses due to evaporation.

The situation appears to be reversed with regard to wheeled ORVs. Although no rigorous research reports were found in this review, the Bureau of Land Management report on the California Desert contains persuasive observations. The acceleration of both wind and water erosion which undeniably occurs must surely increase water turbidity. In addition, the reduction of vegetation on slopes must also lead to increased runoff at the expense of infiltration and thus increase erosion and hence turbidity. Effects in other portions of the nation were not found, but must certainly be reflected in erosional response to particular conditions of soil type, intensity of vehicle use and rainfall, type and coverage of vegetation, etc.

ADMINISTRATIVE ASPECTS

In a study of ORV problems (McCool and Roggenbuck), administrative problems were identified as the second most frequently mentioned set of issues dealing with ORVs on public lands in the west; respondents were deliberately diverse--land managers, academicians, conservation groups, and ORV user groups.

Regulations and legislation, enforcement, methods of providing ORV opportunities, liability and legal problems, fees and permits, and management techniques seem to be the principal administrative questions.

Regulations and Legislation

The controversial nature of off-road vehicles is evidenced by increases in public hearings, state and national legislation, and local regulations.

Most of these regulatory statutes are aimed at control over the ORV operator, reduction of environmental damage, protecting the health and safety of the citizens, and establishing organizations for licensing, administration, and on-the-ground management.

A model state ORV law has been developed by the Upper Great Lakes Regional Commission. While it is not the only attempt at comprehensive uniform legislation (see U. S. Congress, 92nd, H. R. 17158, Snowmobile Recreation and Safety Act; National Committee on Uniform Traffic Laws and Ordinances and Council of State Governments) it is readily available for examination and appears to launch a good attack on many administrative, legal, and financial problems.

Enforcement

Few ORV studies have specifically addressed the enforcement of ORV regulations, other than to identify enforcement as a problem. Perhaps managers need to look toward existing enforcement agencies for general assistance and toward criminological theory and practice for specific techniques.

The reaction of individual users to regulation probably influences the depth of an enforcement program. For example, Kopischke found that about 74% of the snowmobilers in Minnesota found the existing regulations just right, 11% felt there were too many, and 15% thought there were too few.

In summary, a variety of factors--including the manager's authority, his ability to enforce, his perceptions of enforcement and regulations, and the users' general outlook in life--will assist the manager in specifying the extent of the enforcement "problem".

Management Techniques

Managerial implications of the above research would seem both numerous and diverse. In spite of this, few investigations relating to direct management of ORVs were found. A notable exception was an evaluation of snowmobile controls tested in various parts of the snowbelt; this was presented in the Proceedings of the 1970 International Snowmobile Conference held in Duluth (Minnesota Department of Economic Development, p. 113-150). Unfortunately that document was unavailable at the time of this report's preparation.

Conceptually, five major types of management techniques or controls may be visualized: judicial decisions, legislative directives, executive directives, agency regulations, and specific management techniques.

The courts have recently entered the picture through suits such as the challenge of ORV regulations promulgated by the U. S. Bureau of Land Management. As a result of that suit, the regulations were rescinded by the court, and the Bureau must propose new regulations.

Congress has passed few laws dealing directly with the ORV situation, other than isolated instances such as the Wilderness Act (U. S. Congress, 1964a) which forbade motorized travel within the National Wilderness Preservation System, and the so-called Anti-Tote-Gote Act (U. S. Congress, 1964b) which provided for immediate U.S. Commissioner Court trials of ORV drivers invading wilderness.

Executive directives appeared with President Nixon's Executive Order 11644 (U. S. President), which recognized the need to regulate off-road vehicles and required that federal land-managing agencies promulgate appropriate regulations within a few months of passage of the Order.

Direction by agency administrators followed with separate off-road vehicle regulations promulgated by the Department of the Interior, Department of Agriculture, and Department of Defense.

Many state legislatures have passed regulatory legislation covering ORVs; details were discussed earlier in the section on Legislation.

Most of the specific suggestions for management techniques have come directly from managers rather than through research aimed directly at optimizing management. Favored measures have included more education of ORV operators, special zones for ORV use, more ORV areas and trails, improved design of areas and trails, and self-regulation by ORV operator groups.

Generalized research on management techniques will often be difficult to design. This is because many problems facing ORV managers today and in the forseeable future are unique to a particular decision-making locality; they are situation-specific. In many instances, optimal solutions will depend primarily upon the manager's creativity and innovative abilities in searching for answers, as well as his aptitude at defining problems rather than treating symptoms.

The major importance of management objectives in constraining or suggesting alternatives for problem resolution has been well identified in wildland recreation literature. For example, an explicit statement of management objectives can permit specification of the amount of ecological change permitted within an ORV use context.

The manager must also consider the ability of the resource to withstand impacts initiated by the presence and use patterns of ORVs. Some areas may require "site hardening" techniques similar to those used in many campgrounds and picnic sites. Managers will need to predict the nature of impacts expected at a given use level and intensity, and determine what techniques, if any, are required for mitigation.

In addition, managers will need to assess the behavior of the ORV operator himself. What are the expectations, preferences, and use patterns of the visitor? What type of vehicle is being used? Where is the site in respect to the user's residence? What expectations do users hold in terms of freedom in use of their machines?

Traditionally, wildland managers have responded to recreation problems through the construction of facilities--campgrounds, restrooms, boat ramps, trails, etc. The focus will probably continue in that direction. Thus, the ORV manager may find himself continually involved in planning, developing, and maintaining facilities to manipulate ORV opportunities. Trails, roads, campgrounds, sewage systems, signs and more are all facilities the manager may use as techniques to solve ORV-related problems.

Of increasing significance in the repertoire of techniques available are programs directed at securing greater levels of visitor satisfaction, and changes in user activities so as to reduce resource degradation and depreciative behavior.

In conclusion, given a certain situation and identified constraints (e.g. management objectives, ecological capacities, and ORV user behavior), the manager has available a kit of tools (facilities, visitor management, and landscape modification) which he may apply to solve those problems facing him. Rarely will one technique be completely effective in resolving the difference between the existing and the desired situation. The mix of tools selected by the manager will be a function of situational constraints, the manager's creative abilities, and his estimation of the effectiveness of each technique to achieve accepted management goals.

SUGGESTIONS FOR RESEARCH

In reviewing the relevant literature on off-road vehicles, the authors identified many researchable questions. It was beyond the scope of this paper to list these questions in any manner of priority; readers interested in such a prioritized array are referred to McCool and Roggenbuck. The several questions below are selected as representative of current researchable ORV-related problems.

1. What planning and management techniques would reduce or avoid conflicts (a) among ORV users, (b) between ORV users and other land users and, (c) between ORV users and land managers?

2. What are the differential effects of specified types and weights of ORVs on erosion and water quality under different specified conditions of soil type, soil moisture, soil density, surface slope, and vegetative cover?

3. What is the effect of ORVs on animals during periods of breeding and early growth?

4. What design standards for both trails and ORVs could be adopted to reduce ORV impact?

5. What are the similarities and differences in terms of resource and facility needs among the various types of ORVs?

6. Of what relative importance and/or value to the "ORV experience" are (a) natural resources and (b) facilities?

7. To what extent will a substantial reduction in vehicular noise levels be effective in reducing animosity toward ORV use?

8. What are the similarities and differences in characteristics of use among families, organized groups, and individuals?

9. How does age, experience, and type of ORV influence rider expectations?

10. Does ORV operation substitute for other activities, and vice versa? If so, what are those activities? Can they be used to supplement ORV areas or serve as alternative uses?

11. What techniques can be used to more effectively communicate among ORV users, non-users, and managers?

12. What non-ORV recreation activities can safely occur on trails and areas which are simultaneously being used by ORVs?

13. What are the circumstances under which accidents involving ORVs are most likely to occur?

14. How can land managers most effectively enforce ORV regulations regarding land closures and restrictions?

15. What criteria should be used to determine which areas receive priority for development of ORV areas?

16. What are the professional and personal characteristics of those managers who are most effective in dealing with ORV problems?

17. What causes some ORV users to heavily damage the land, to create social conflicts and to violate regulations?

Because most ORV research has concerned snowmobiles, it is important that future research emphasize other ORVs so that managers can deal more effectively with problems induced by this challenging recreational activity.

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BIBLIOGRAPHY

1. Ahern, Catherine A. 1975. Letter to Richard L. Bury dated June 11, 1975, from Catherine A. Ahern, Manager of Information Services, International Snowmobile Industry Association, Arlington, Virginia.

2. Allan, Nigel J. R. 1975. Man, Machine, and Snow: A Study of Recreationists' Landscape Perceptions. Discussion Paper Series #2, Department of Geography, Syracuse University. The Department, Syracuse, New York, 20 p.

3. Allsop, R. E. 1967. Costs and Benefits If All Motorcyclists Wore Safety Helmets. Road Research Laboratory, Crowthorne, England, 23 p.

4. American Association for the Advancement of Science, Committee on Arid Lands. 1974. "Off-Road Vehicle Use." Science 184(4135): 500-501.

5. American Honda Motor Company. n.d. "A Study of the Purchase Decision Process." Excerpts from an incomplete report. The Company, Gardena, California. Cited at page 9 in J. E. Fluharty. 1971. Motorized Recreation Vehicles: Roles of Recreation and Parks. Recreation and Youth Service Planning Council, Los Angeles, California, 93 p.

6. American Motorcycle Association. Motorcycle Noise Control. The Association, Westerville, Ohio, 7 p.

7. Anonymous. 1973. "Snowmobiles and Environment." Yale Law Journal 82(4):772-786.

8. Armstrong, Jack. 1973. "Snoplan--A Trail Development and Maintenance Program," in Holecek, 1973 Proceedings . . ., op. cit., p. 168-175.

9. Baldwin, Malcolm F. 1970. The Off-Road Vehicle and Environmental Quality. The Conservation Foundation, Washington, D. C., 52 p.

10. Baldwin, Malcolm F. and Dan H. Stoddard, Jr. 1973. The Off-Road Vehicle and Environmental Quality, 2nd Ed. Conservation Foundation, Washington, D.C., 61 p.

11. Banzhaf, George & Co. 1974. *United States Forest Service Survey for Use of Off-Road Vehicles*. Prepared for Nicolet, Chequamegon, Ottawa, and Hiawatha National Forests. George Banzhaf and Co., Milwaukee, 53 p. + unpaginated Appendix.

12. Berglund, Bob. 1972. "National Policy for Snowmobiles." *Congressional Record*, October 14, 1972, E-8626.

13. Berry, K. (Ed.) 1973. *Preliminary Studies on the Effects of Off-Road Vehicles on the Northwestern Mojave Desert: A Collection of Papers*. Privately printed, Ridgecrest, California, 100 p.

14. Bess, F. H. 1971. "The Effect of Snowmobile Engine Noise on the Hearing Mechanism," in Chubb, Michael (Editor), *Proceedings of the 1971 Snowmobile and Off-The-Road Vehicle Research Symposium*, Michigan State University. East Lansing, p. 147-158.

15. Bess, F. H. 1973. "The Effectiveness of Helmets for Ear Protection," in Holecek, Donald F. (Editor). *Proceedings of the 1973 Snowmobile and Off The Road Vehicle Research Symposium* sponsored by the Department of Park and Recreation Resources, Michigan State University. Technical Report #9. Recreation Research and Planning Unit of the Department, East Lansing, Michigan, p. 147-156.

16. Bess, F. H. and R. E. Poynor. 1972. "Snowmobile Engine Noise and Hearing." *Archives of Otolaryngology* 95:164-168.

17. Bollinger, John G., Orrin J. Rongstad, Andres Soom, and Ronald G. Eckstein. 1973. *Snowmobile Noise Effects on Wildlife, 1972-1973 Report*. Engineering Experiment Station, University of Wisconsin, Madison, Wisconsin, 85 p.

18. Brander, Robert B. 1974. "Ecological Impacts of Off-Road Recreational Vehicles," in U. S. Department of Agriculture, Forest Service, North Central Experiment Station. 1974. *Outdoor Recreation Research: Applying the Results*, papers from a workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. U. S. Government Printing Office, Washington, D. C., p. 29-35.

19. Brown, Tommy L. 1973. *Posting of Private Lands in New York: Incidence and Causes*. Conservation Circular, Department of Natural Resources, Cornell University, Vol. 11, No. 4. The Department, Ithaca, New York, 8 p.

20. Brown, T. 1974. *Guidelines for Snowmobile Trail Planning*. Conservation Circular, 12(4). Department of Natural Resources, Cornell University, Ithaca, New York, 4 p.

21. Brown, T. L. and G. H. Hill. 1973. "The New York Snowmobiler and the Private Landowner," in Holecek, 1973 Proceedings . . ., op. cit., p. 33-39.

22. Bury, R. L. and E. Fillmore. 1974. Design of Motorcycle Areas Near Campgrounds: Effects on Riders and Nonriders, Technical Report No. 6, Department of Recreation and Parks, Texas A&M University and Texas Agricultural Experiment Station. The Department, College Station, Texas, 61 p.

23. Butler, Richard W. 1974. "How to Control 1,000,000 Snowmobiles." Canadian Geographical Journal 88(3):4-13.

24. California Resources Agency, Department of Parks and Recreation. 1974. "Off-Highway Vehicle Activities Status Report: July 1972 through July 1974." The Agency, Sacramento, 3 p.

25. Carter, Luther J. 1974. "Off-Road Vehicles: A Compromise Plan for the California Desert." Science 183(4123):396-399.

26. Cherniak, Earl. 1971. Untitled presentation within Product Safety Panel, in University of Western Ontario, Faculty of Law, Proceedings . . ., op. cit., p. 73-79, 89-90, 97, 100.

27. Chilman, K. C. and K. Kupcikevicius. 1973. "Profile: The Trail-Biker." Unpublished paper presented at Trail Bike and Land Use Planning Institute, Lake Barkley State Park, Cadiz, Kentucky. Report available from authors, Southern Illinois University, Carbondale, Illinois, 11 p.

28. Chubb, Michael (Editor), 1971. Proceedings of the 1971 Snowmobile and Off The Road Vehicle Research Symposium sponsored by the Department of Park and Recreation Resources and the Agricultural Experiment Station, both of Michigan State University, and the U. S. Bureau of Outdoor Recreation. Technical Report #8. Recreation Research and Planning Unit of the Department, East Lansing, Michigan, 196 p.

29. Clark, R. N., J. C. Hendee, and F. L. Campbell. 1971. Depreciative Behavior in Forest Campgrounds: An Exploratory Study. USDA Forest Service Research Note PNW-161. Pacific Northwest Forest and Range Experiment Station, Seattle, Washington, 12 p.

30. Collins and Aley. 1968. "Investigation of Motorcycle Damage on Ava Ranger District." Unpublished report on file at office of Mark Twain National Forest, Springfield, Missouri.

31. Conservation Foundation. 1972. "A Statutory Guide: Snowmobiles and Other Off-Road Vehicles." Trends in Parks and Recreation 9(3):23-27.

32. Cooney and Preston. 1971. "Snowmobiles: A Legislative Program." University of Wisconsin.

33. Dahms, B. A. 1970. "Legislative Notebook: Off-Road Survey Surprises." Cycle News 6(50):15.

34. Davidson, Eric and Martha Fox. 1974. "Effects of Off-Road Motorcycle Activity on Mojave Desert Vegetation and Soil." Madrono 22(8):381-390.

35. Doan, R. K. 1970. "Effect of Snowmobiles on Fish and Wildlife Resources," in Proceedings, 60th Convention of the International Association of Game, Fish and Conservation Commissioners, September 16-18. Litho Productions for the Association, Madison, Wisconsin, p. 97-103.

36. Doherty, Paul. Undated. "Effects on Fish and Game Management," in U. S. Senate, 1971, Hearing on Snowmobiles . . ., op. cit., p. 62-63.

37. Dorrance, Michael J., Patrick J. Savage, and Dan E. Huff. 1973. "Effects of Snowmobiles on White-Tailed Deer -- Progress Report, 1973." Unpublished report on file at office of authors, Department of Entomology, Fisheries, and Wildlife, University of Minnesota, Minneapolis, 30 p.

38. Dorrance, Michael J., Patrick J. Savage, and Dan E. Huff. 1975. "Effects of Snowmobiles on White-Tailed Deer." Journal of Wildlife Management 39(3): In press.

39. Doyle, M. B. 1974a. An Assessment of the Snowmobile Manufacturing Industry, 1975-1979. International Snowmobile Industry Association, Falls Church, Virginia, 16 p.

40. Doyle, M. B. 1974b. Position of the International Snowmobile Industry Association on Snowmobile Sound Level Requirements. International Snowmobile Industry Association, Falls Church, Virginia, 15 p.

41. Doyle, M. B. 1974c. Recreation and Man. International Snowmobile Industry Association, Arlington, Virginia, 15 p.

42. Doyle, Mortimer B. 1975. An Assessment of the Snowmobile Manufacturing Industry and Sport. International Snowmobile Industry Association, Arlington, Virginia, 15 p.

43. Doyle, Patrick. 1973. "Advancements by the Industry in the Environmental Area since 1971," in Holecek, 1973 Proceedings . . ., op. cit., p. 77-85.

44. Dunn, Diana R. 1970. "Motorized Recreation Vehicles--On Borrowed Time." Parks and Recreation 5(7):10-14, 46-52.

45. Dunn, Diana R. 1971. "Trends in Snowmobile and Off-The-Road Vehicle Legislation: Effects on Use and Environmental Impact," in Chubb, 1971 Proceedings . . ., op. cit., p. 163-169.

46. Dunn, Diana R. 1973. "Off-the-Road Vehicles: The View From Now," in Holecek, 1973 Proceedings . . ., op. cit., p. 200-202.

47. English, John W. 1972. Laws Regulating Off-Highway Vehicles. Entire issue, Traffic Laws Commentary 1(8):1-109 (Published by U. S. Department of Transportation, National Highway Traffic Safety Administration; printed by U. S. Government Printing Office, Washington, D. C.)

48. Ferrin, R. S. and G. B. Coltharp. 1974. "Lead Emissions from Snowmobiles as a Factor in Lead Contamination of Snow," in Proceedings Utah Academy of Sciences, Arts, and Letters. Brigham Young University, Provo, Utah, p. 116-118.

49. Fleming, J. P. 1969. "Safety Committee Report," in USDI Bureau of Outdoor Recreation, Proceedings, 1969 International Snowmobile Conference, op. cit., p. 23-27.

50. Fleming, John P. 1973. "ORV Safety--How Can the Record be Improved?" in Holecek, 1973 Proceedings . . ., op. cit., p. 130-134.

51. Fluharty, J. E. 1971. Motorized Recreation Vehicles: Roles of Recreation and Parks. Recreation and Youth Service Planning Council, Los Angeles, California, 93 p.

52. Fogg, G. E. 1971. "Trails for Motorized Vehicles," in Proceedings, National Symposium on Trails sponsored by USDI Bureau of Outdoor Recreation. U. S. Government Printing Office, Washington, D. C., p. 46-48.

53. Giacomini, Larry. 1974. "Running It Into the Ground: A Special ORV Report Guide to ORV's," Western Outdoor Annual, Spring 1974: 4-27.

54. Gogebic Community College, in cooperation with Upper Great Lakes Regional Commission and Michigan Department of Natural Resources. 1974a. Michigan Snowmobiler Economic and Preference Survey. The Commission (?), Duluth, Minnesota, 83 p. + appendix.

55. Gogebic Community College, in cooperation with Upper Great Lakes Regional Commission, Michigan Department of Natural Resources, Minnesota Department of Natural Resources, and Wisconsin Department of Natural Resources. 1974b. Three-State Snowmobiler Economic and Preference Survey. The Commission, Duluth, Minnesota, 92 p. + appendix.

56. Gogebic Community College and Upper Great Lakes Regional Commission. Undated (c. 1974). Snowmobiles--A Challenging Opportunity. The Commission, Duluth, Minnesota, 12 p.

57. Griffith, Richard E. 1969. "Environmental Quality Impact," in USDI, Bureau of Outdoor Recreation and New York State Conservation Commission, Proceedings, International Snowmobile Conference, May 20-21. U. S. Government Printing Office, Washington, D. C., p. 5-8.

58. Harano, R. M. and R. C. Peck. 1968. The California Motorcycle Study, Driver and Accident Characteristics. California Department of Motor Vehicles, Sacramento, California, 39 p.

59. Harrison, R. 1973. The Effectiveness of Motorcycle Helmets as Hearing Protectors. Equipment Development and Testing Project Record 2210. San Dimas Equipment Development Center. U. S. Forest Service, San Dimas, California, 28 p.

60. Harrison, R. 1974a. All-Terrain Vehicle Noise. Equipment Development and Testing Project Record 2524. San Dimas Equipment Development Center, U. S. Forest Service. San Dimas, California, 8 p.

61. Harrison, R. 1974b. Motorcycle Noise. Equipment Development and Testing Project Record 2428. San Dimas Equipment Development Center, U. S. Forest Service. San Dimas, California, 30 p.

62. Harrison, R. 1974c. Snowmobile Noise. Equipment Development and Testing Project Report 7120-5. San Dimas Equipment Development Center, U. S. Forest Service. San Dimas, California, 48 p.

63. Harrison, R. 1974d. Sound Propagation and Annoyance Under Forest Conditions. Equipment Development and Test Report 7120-6. San Dimas Equipment Development Center, U. S. Forest Service, San Dimas, California, 35 p.

64. Hetherington, J. W. 1971a. "A Survey of Snowmobile Trail Facilities," in Chubb, 1971 Proceedings . . ., op. cit., p. 72-80.

65. Hetherington, John W. 1971b. "The Snowmobile," in Recreation Symposium Proceedings, published transactions from the Forest Recreation Symposium held at Syracuse, New York by State University of New York College of Forestry, U.S.D.A. Forest Service, and others. U. S. Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, p. 143-148.

66. Hill, Gregory A. 1971. "Towards Enhancing and Controlling Recreational Snowmobiling: A Study of Central New York Participants and Vehicle Use." Unpublished master's thesis on file at Department of Natural Resources, Cornell University, Ithaca, New York, 59 p.

67. Hill, Gregory A. 1974. "Central New York Snowmobiles and Patterns of Vehicle Use." Journal of Leisure Research 6(Fall):280-292.

68. Hogan, A. W. 1972. "Snowmelt Delay by Oversnow Travel." Water Resources Research 8:174-175.

69. Holecek, D. F. 1973a. "ORV User Characteristics and Behavior Workshop Report," in Holecek, 1973 Proceedings . . ., op. cit., p. 53-55.

70. Holecek, Donald F. (Editor) 1973b. Proceedings of the 1973 Snowmobile and Off The Road Vehicle Research Symposium sponsored by the Department of Park and Recreation Resources, Michigan State University. Technical Report #9. Recreation Research and Planning Unit of the Department, East Lansing, Michigan, 202 p.

71. Hollenbaugh, William C. 1969. "Trails and Signs Design," in USDI Bureau of Outdoor Recreation, Proceedings, 1969 International Snowmobile Conference, op. cit., p. 9-21.

72. Huff, Dan E., Patrick J. Savage, David L. Urich, and Robert L. Watlov. 1972. Wildlife-Snowmobile Interaction Project, Preliminary Report covering November 1971-April 1972. University of Minnesota and Minnesota Department of Natural Resources, Place of publication and publisher not stated, 34 p.

73. International Snowmobile Industry Association. 1974a. Position of the International Snowmobile Industry Association on the Energy Emergency. The Association, Washington, D. C., 16 p.

74. International Snowmobile Industry Association. 1974b. "Summary of Snowmobile Laws and Regulations," Large, double-sided chart. The Association, Arlington, Virginia.

75. International Snowmobile Industry Association. 1975. Untitled news release dated May 23, 1975. The Association, Arlington, Virginia, 1 p.

76. International Snowmobile Industry Association. c. 1975. Position of the International Snowmobile Industry Association on Snowmobile Sound Level Requirements. The Association, Falls Church, Virginia, 15 p.

77. Janoff, M. S., A. Cassel, K. S. Fertner, and E. S. Smierciak. 1970. Daytime Motorcycle and Taillight Operation. Franklin Institute Research Laboratories, Philadelphia, Pennsylvania, 185 p.

78. Jarvinen, Julie A., and William D. Schmid. 1971. "Snowmobile Use and Winter Mortality of Small Mammals," in Chubb, 1971 Proceedings . . ., op. cit., p. 130-140.

79. Johnson, P., B. Kennedy, J. Meisenback, and R. Rawlings. 1974. Off-Highway Vehicle Registrants--A Survey of Their Interests and Activities." in Rec Tip, No. 7. California Resources Agency, Department of Parks and Recreation, Sacramento, California, 71 p.

80. Keenan, W. J. 1971. Untitled commentary in University of Western Ontario, Faculty of Law, Proceedings . . ., op. cit., p. 216.

81. Knopp, T. B. and J. D. Tyger. 1973. "A Study of Conflict in Recreational Land Use: Snowmobiling vs. Ski-Touring," Journal of Leisure Research 5(3):6-17.

82. Kopischke, Earl D. 1973. "Characteristics of the Snowmobiler and His Activity in South-Central Minnesota." Minnesota Game Research, Special Report. Minnesota Department of Natural Resources, St. Paul, p. 65-70.

83. Kuehn, J. H. 1971. "Minnesota's 1970 Snowmobile Use Study," in Chubb, 1971 Proceedings . . ., op. cit., p. 19-28.

84. Lanier, L. L. and M. Chubb. 1971. "Michigan's 1970 Snowmobile Study," in Chubb, 1971 Proceedings . . ., op. cit., p. 55-71.

85. Lime, David W. and Earl C. Leatherberry. 1974. "Off-Road Recreation Vehicle (ORRV) Bibliography." Unpublished report on file at office of Dr. David Lime, USDA Forest Service, North Central Forest Experimental Station, Folwell Avenue, St. Paul, Minnesota, 16 p.

86. Lime, David W. and G. H. Stankey. 1971. "Carrying Capacity: Maintaining Outdoor Recreation Quality," in Recreation Symposium Proceedings, published transactions from the Forest Recreation Symposium held at Syracuse, New York by State University of New York College of Forestry, USDA Forest Service, and others. U. S. Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, p. 174-184.

87. Lindsay, John J. 1974. Outdoor Recreation Conflict in Vermont, 1973. Research Report SNR-RM2. School of Natural Resources, University of Vermont, Burlington, 46 p.

88. Lodico, Norma Jean. 1973. Environmental Effects of Off-Road Vehicles: A Review of the Literature. Bibliography Series No. 29, Research Services Branch, Office of Library Services, U. S. Department of the Interior. The Department, Washington, D. C., 112 p.

89. Lunenfeld, H. and R. G. Varady. 1970. Performance Requirements for Motorcycle Helmets. AIL, Deer Park, New York, 251 p.

90. Malaher, G. W. 1967. "Improper Use of Snow Vehicles for Hunting," *Transactions*, 32nd North American Wildlife and Natural Resources Conference, Wildlife Management Institute, San Francisco, March 13-15. The Institute, Washington, D. C., p. 429-433.

91. Malo, John W. 1971. *Snowmobiling: The Guide*. Macmillan, New York, 185 p.

92. Manning, R. 1973. "A Study of the Michigan Program of Private Land Leasing for Snowmobile Use," in Holecek, *1973 Proceedings . . .*, *op. cit.*, p. 176-182.

93. McCay, Roger and George Moeller. 1975. "Trail Talk." Report on file at office of USDA, Forest Service, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, 9 p.

94. McCool, S. F. 1974. "Off-Road Vehicles: Problems and Priorities." *Utah Recreation and Tourism Review* 3(3):1-3.

95. McCool, S. F. and J. W. Roggenbuck. 1974. *Off-Road Vehicles and Public Lands: A Problem Analysis*, Volumes 1 and 2. Department of Forestry and Outdoor Recreation and Institute for the Study of Outdoor Recreation and Tourism, College of Natural Resources, Utah State University, Logan, Utah, 63 p. and 109 p., respectively.

96. McCool, S. F., W. H. Becker, J. D. Hunt, R. M. Schreyer, and P. J. Urness. 1975. "Little Sahara Recreation Area and Off-Road Vehicles: Problems, Priorities, and Promising Solutions." Unpublished contract research report funded through Utah State University Foundation, North Logan, Utah. Copies available from S. F. McCool, College of Forestry, Utah State University, Logan, 63 p.

97. McLay, R. W. 1969. "Snowmobile Safety Committee Report," in USDI Bureau of Outdoor Recreation, *Proceedings, 1969 International Snowmobile Conference*, *op. cit.*, p. 27-31.

98. Michael, M. J. 1973. "Research briefs: summary of a survey on off road vehicles." *Parks and Recreation* 8(2):39-41.

99. Michalson, Edgar L. 1973. "Methodology for Determining the Economic Impact of ORV's," in Holecek, *1973 Proceedings . . .*, *op. cit.*, p. 120-129.

100. Mietz, James D. 1974. "Snowmobile Impact on Forest Vegetation at Heiberg Forest, New York." Unpublished Master's thesis on file at State University of New York, College of Environmental Science and Forestry, Syracuse, New York, 119 p.

101. Miller, Mead P. 1973. *Motorcycle Park Planning and Management*. Motorcycle Industry Council, Washington, D.C., 24 p.

102. Miller, Philip. 1970. "Case Study No. XVI; Off-Road Recreational Vehicle Composite," in Public Land Policy and the Environment, Part II. Environmental Problems on the Public Lands. PB 196 170. National Technical Information Service, Springfield, Virginia, 3:730-767.

103. Minnesota Department of Economic Development. 1970. Proceedings, 1970 International Snowmobile Congress, Duluth, Minnesota. The Department, St. Paul, Minnesota, 222 p.

104. Moeller, George H. 1971. The Landowner and the Snowmobiler--Problem or Profit? U.S.D.A. Forest Service Research Paper NE 206. U. S. Department of Agriculture, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania, 15 p.

105. Muntz, E. P., T. L. Deglow, and D. H. Campbell. 1972. Public Lands and Off-Road Motorized Recreation. Environmental Engineering Programs Bulletin 100. School of Engineering, University of Southern California, Los Angeles, California, 18 p.

106. National Committee on Uniform Traffic Laws and Ordinances, and Council of State Governments. 1973. "Proposed Law to Regulate Off-Highway Traffic." The Committee(?) or Council(?), Washington, D. C., 24 p.

107. National Research Council of Canada, Division of Physics. 1970. Snowmobile Noise: Its Sources, Hazards and Control, APS-477, Acoustics Section, Division of Physics, National Research Council of Canada, Ottawa, 36 p.

108. Newby, F. 1971. "Why Trails for Motorized Vehicles," in Proceedings, National Symposium on Trails. U. S. Department of the Interior, Bureau of Outdoor Recreation, Washington, D. C., p. 51-53.

109. Newmann, P. W., and H. Gray Merriam. 1972. "Ecological Effects of Snowmobiles." Canadian Field - Naturalist 86:207-212.

110. Nicholi, A. M. 1970. "The Motorcycle Syndrome." American Journal of Psychiatry 126(11):1588-1595.

111. Ontario Department of Tourism and Information. 1971. An Analysis of Snowmobiling in Ontario, Winter 1969-1970. The Department, Toronto, Canada, 111 p.

112. Opolka, Frank, et al. 1973. "Panel Discussion on ORV Policy and Regulation on Public Lands," in Holecek, 1973 Proceedings . . ., op. cit., p. 183-197.

113. Peine, J. 1969. "A Comparison of the Recreation Use Patterns of the Tucson Jeep Club and Tucson Sandbuggy Association." Unpublished M.S. thesis on file at Department of Watershed Management, University of Arizona, Tucson, 85 p.

114. Peine, John Douglas. 1972. "Land Management for Recreational Use of Off-Road Vehicles." Unpublished Ph.D. dissertation on file at Department of Watershed Management, University of Arizona, Tucson. 196 p.

115. Pendleton, John W. 1972. "Effects of Snowmobile Traffic on Non-Forest Vegetation." Progress Report, Cooperative Research, Agronomy and Experimental Farms, University of Wisconsin-Madison. Department of Agronomy, University of Wisconsin, Madison, 25 p.

116. Pendleton, J. W., R. N. Walejko, W. H. Paulson, R. E. Rand, G. H. Tenpas, and D. A. Schlough. 1972. Effects of Snowmobile Traffic on Non-Forest Vegetation. Progress Report, University of Wisconsin-Madison, Cooperative Research, Agronomy and Experimental Farms. The University, Madison, Wisconsin, 25 p.

117. Penny, J. R. 1971. "Off-Road Vehicles on the Public Lands in California," in Chubb, 1971 Proceedings . . ., op. cit., p. 95-110.

118. Percy, E. C. 1972. "The Snowmobile--Friend or Foe." Journal of Trauma 12(5):444-446.

119. Petrie, B. M. "The Snowmobile and All-Terain Vehicle as a Generator of Social Conflict in Canada: A Speculative Approach," in Proceedings of Conference on Snowmobiles and All Terrain Vehicles, sponsored by Faculty of Law, University of Western Ontario. The Faculty, London,Ontario, Canada, p. 5-10.

120. Pleuther, R. L. 1969. A Critique on the Performance of Off-Road Vehicles: Full Scale Test Results and Prediction Method Evaluation. Connell Aeronautical Laboratory, Inc., Buffalo, New York, 79 p.

121. Plumb, S. S. 1972. "An Analysis of Perceived Attitudes Toward Environmental and Sociological Effects of the Recreational Use of Off-Road Vehicles at the Back Bay National Wildlife Refuge." Unpublished M.S. thesis on file at The Pennsylvania State University, University Park, 145 p.

122. Potter, Howard L. c. 1970. "Social and Political Impact," quoted in U. S. Senate, 1971, Hearing . . ., op. cit., p. 64-65.

123. Power, J. A. and E. G. Schuster. 1975. Off-Road Vehicle Law in Idaho: An ORV Planning Aid. Information Series #11, College of Forestry, Wildlife, and Range Sciences, University of Idaho. The College, Moscow, Idaho, 65 p.

124. Poynor, R. E. and F. H. Bess. 1972. "Hearing Loss of Apparent Sudden Onset Associated with Snowmobile Noise." MSHA (Michigan Speech and Hearing Association?) Journal 8(2):85-91.

125. Pruitt, William O. 1971. "Some Ecological Effects of Snowmobiles." Brief presented to Winnipeg Council, January. Unpublished manuscript available from the author, Winnipeg, Canada, 4 p.

126. Rand, J. A. 1969. "Environmental Factors in Snowmobile Safety, Committee Report," in U.S.D.I. Bureau of Outdoor Recreation, *Proceedings, 1969 International Snowmobile Conference*, *op. cit*., p. 36.

27. Richardson, H. A. 1974. *A Motorcycle Safety Helmet Study*. U. S. Department of Transportation, National Highway Traffic Safety Administration, Washington, D.C. 44 p.

28. Rickard, Warren E. Jr. and Jerry Brown. 1974. "Effects of Vehicles on Arctic Tundra," *Environmental Conservation* 1(1):55-62.

29. Roggenbuck, J. W. and S. F. McCool. 1974. "Some Behavioral Issues in Providing Off-Road Recreation Vehicle Opportunities on Public Lands," paper presented to the Natural Resources Section, Utah Academy of Sciences, Brigham Young University. Available from the authors, Institute for the Study of Outdoor Recreation and Tourism, Utah State University, Logan, 15 p.

30. Schemnitz, Sanford D. and James L. Schortemeyer. 1973. "The Impact of Halftracks and Airboats on the Florida Everglades Environment," in Holecek, *1973 Proceedings . . .*, *op. cit*., p. 86-117.

31. Schmid, W. D. 1971a. "Modification of the Subnivean Microclimate by Snowmobiles," in *Proceedings of Snow and Ice Symposium*. Cooperative Wildlife Research Unit, Iowa State University, Ames, Iowa, p. 251-257.

32. Schmid, William D. 1971b. "Modification of the Subnivean Microclimate by Snowmobiles," *in* U. S. Congress, Senate, 1971, *Hearings . . .*, *op. cit*., p. 105-107.

33. Schmid, William D. 1972. "Snowmobile Activity, Subnivean Microclimate and Winter Mortality of Small Mammals." Abstract of paper presented at 1972 Meeting, American Institute of Biological Scientists, University of Minnesota. *Bulletin of the Ecological Society of America* 53(2):37.

34. Scholwin, Susie. 1971. Untitled testimony *in* U. S. Congress, Senate, 1971, *Hearing . . .*, *op. cit*., p. 49-68.

35. Shute, Eldin. 1970. Welcoming Address to Third Annual International Snowmobile Congress, Portland, Maine; quoted *in* U. S. Congress, Senate, 1971, *Hearing . . .*, *op. cit*., p. 59.

36. Simard, Jacques. 1971. Untitled commentary *in* University of Western Ontario, Faculty of Law, *Proceedings . . .*, *op. cit*., p. 216.

137. Smith, B. H. and L. P. Delner. 1969. "Fatal Motorcycle Accidents of Military Personnel: A Study of 233 Cases." *Military Medicine* 134(13):1477-1487.

138. Snowmobile Safety and Certification Committee, Inc. 1974. *Minimum Safety Standards for Snowmobile Product Manufacture*. The Committee, Arlington, Virginia, 35 p.

139. Snowmobile Saftey and Certification Committee, Inc. 1975. *Snowmobiler's Safety Handbook*. The Committee, Arlington, Virginia, 38 p.

140. Soom, Andres, John G. Bollinger, and Orrin J. Rongstad. 1972. "Studying the Effects of Snowmobile Noise on Wildlife," *Inter-noise 72 Proceedings*:236-241.

141. Stahl, M. and F. H. Bess. 1973. "The Snowmobiler and Noise," in Holecek, *1973 Proceedings . . .*, *op. cit.*, p. 157-167.

142. Stebbins, Robert C. 1974a. "Off-Road Vehicles and the Fragile Desert." *American Biology Teacher* 36(4):203-208, 220.

143. Stebbins, Robert C. 1974b. "Off-Road Vehicles and the Fragile Desert." *American Biology Teacher* 36(5):294-304.

144. Stupay, Arthur M. 1971. "Growth of Powered Recreation Vehicles in the 1970's," in Chubb, *1971 Proceedings . . .*, *op. cit.*, p. 14-18.

145. U. S. Congress. 1964a. *An Act to Establish a National Wilderness Preservation System . . ., Public Law 88-577*. The Congress, Washington, D. C., 7 p.

146. U. S. Congress. 1964b. *An Act to Provide for Enforcement of Rules and Regulations . . . of the National Forests . . ., Public Law 88-537*. U. S. Government Printing Office, Washington, D. C., 1 p.

147. U. S. Congress. 1972a. *An Act to Control the Emission of Noise Detrimental to the Human Environment, and for Other Purposes, Public Law 92-574*. The Congress, Washington, D. C., 16 p.

148. U. S. Congress, House of Representatives. 1972b. "H. R. 17158, To Establish a National Policy Regarding Recreational Use of Snowmobiles on Public Lands, to Provide for a Coordinated National Snowmobile Safety Program, and for Other Related Purposes." The Congress, Washington, D. C.

149. U. S. Congress, Senate Committee on Interior and Insular Affairs, Subcommittee on Parks and Recreation. 1971. *Hearing on Snowmobiles and Other Off-Road Vehicles*, May 21. U. S. Government Printing Office, Washington, D. C., 109 p.

150. U. S. Congress, Senate Committee on Interior and Insular Affairs, Subcommittee on Public Lands. 1974. Hearing on S. 63, a Bill to Establish the Califronia Desert National Conservation Area. U. S. Government Printing Office, Washington, D. C., 532 p.

151. U. S. Department of Agriculture. 1974. Standard for Spark Arrestors for Internal Combustion Engines. ER 1130-2-405. The Department, Washington, D. C., 11 p.

152. U. S. Department of Agriculture, Forest Service. 1973a. Final Environmental Statement, Proposed Off-Road Vehicle Regulations and Administrative Instructions. Issued March 14, 1973. The Service (?), Washington, D. C., 13 p. + appendix.

153. U. S. Department of Agriculture, Forest Service. 1973b. "Use of Off-Road Vehicles," Part 295 of Chapter II, Title 36. Federal Register 185:26723-26724.

154. U. S. Department of Agriculture, Forest Service, Eastern Regional Office. 1974. Off-Road Vehicle Policy, Hoosier National Forest: Final Environmental Statement. Eastern Regional Office of the Service, Milwaukee, Wisconsin, 181 p.

155. U. S. Department of Defense, Corps of Engineers. 1974. "Summary of Guidelines, Use of Off-Road Vehicles on Public Lands." Federal Register 39(21):3839-3840.

156. U. S. Department of the Interior, Bureau of Land Management. 1968. The California Desert: A Recreation Study of the Desert Public Domain Lands of California under the Jurisdiction of the Bureau of Land Management. Prepared by the California State Office of the Bureau of Land Management and the Western Regional Office of the National Park Service. The State Office, Sacramento, California, 377 p.

157. U. S. Department of the Interior, Bureau of Land Management. 1974a. "Off-Road Vehicles," Part 6250 and Part 6290 of Title 43. Federal Register 39(73):13613-13615.

158. U. S. Department of the Interior, Bureau of Land Management. 1974b. "Use of Off-Road Vehicles," Chapter II, Title 43. Federal Register 39(73):13612-13613.

159. U. S. Department of the Interior, Bureau of Land Management, California State Office. 1970a. Operation ORVAC: Recommendations and Guidelines for the Management of Off-Road Vehicles on Public Domain Lands in California. The Bureau, California State Office, Sacramento, 40 p.

160. U. S. Department of the Interior, Bureau of Land Management, California State Office. 1970b. The California Desert: A Critical Environmental Challenge. California State Office, the Bureau, Sacramento, California, 70 p.

161. U. S. Department of the Interior, Bureau of Land Management, California State Office. 1974. Final Environmental Impact Statement: Proposed Barstow - Las Vegas Motorcycle Race. California State Office, The Bureau, Sacramento, unnumbered pages.

162. U. S. Department of the Interior, Bureau of Land Management, California State Office. 1975. "Major Rare Intaglio Destroyed on Purpose," BLM Newsbeat August 1975, p. 7.

163. U. S. Department of the Interior, Bureau of Land Management, Utah State Office. Undated (1971). Unpublished memorandum, "Land Report and Environmental Impact Statement (Stump Creek Wildlife Habitat Area, Idaho)." Utah State Office of the Bureau, Salt Lake City, 5 p.

164. U. S. Department of the Interior, Bureau of Outdoor Recreation. 1972. "ORRV Facilities and Legislation at the State Level." Trends in Parks and Recreation 9(3):28-31.

165. U. S. Department of the Interior, Bureau of Outdoor Recreation and New York State Conservation Commission. 1969. Proceedings, 1969 International Snowmobile Conference sponsored by the Lake Central and Northeast Regions of the Bureau, and the Commission. U. S. Government Printing Office, Washington, D. C., 77 p.

166. U. S. Department of the Interior, Task Force on Off-Road Vehicles. 1971. ORRV: Off Road Recreation Vehicles. U. S. Government Printing Office, Washington, D. C., 123 p.

167. U. S. Environmental Protection Agency. 1971. Public Hearings on Noise Abatement and Control, Vol. 5: Agricultural and Recreational Use Noise, September 30--October 1. U. S. Government Printing Office, Washington, D. C., 234 p.

168. U. S. Environmental Protection Agency. 1972. Summary of Noise Control Act of 1972 (PL 92-574). The Agency, Washington, D. C., 9 p.

169. U. S. National Motor Vehicle Safety Advisory Council. 1973. Proceedings of the International Congress on Automotive Safety. U. S. Government Printing Office, Washington, D. C., 3 volumes.

170. U. S. National Transportation Safety Board, Bureau of Surface Transportation Safety. 1972. Safety Aspects of Recreational Vehicles. The Board, Washington, D. C., 38 p.

171. U. S. President (Richard Nixon). 1972. "Use of Off-Road Vehicles on the Public Lands, Executive Order 11644." Federal Register 7(27):2877-2878.

172. U. S. Upper Great Lakes Regional Commission. 1972. Model Legislation: Off-Road Recreation Vehicles. The Commission, Duluth, Minnesota (?), 71 p.

173. University of Western Ontario, Faculty of Law. 1971. Proceedings, Conference on Snowmobiles and All-Terrain Vehicles sponsored by the Faculty. The Faculty, London, Ontario, 237 p.

174. Usher, Peter J. 1972. "Use of Snowmobiles for Trapping on Banks Island." Arctic 25:170-181.

175. Vila, J. J. and P. Klopchic. 1971. "Ontario's 1970 Snowmobile Study," in Chubb, 1971 Proceedings . . ., op. cit., p. 30-42.

176. Waddams, Stephen. 1971. Untitled presentation within Product Safety Panel, in University of Western Ontario, Faculty of Law, Proceedings . . ., op. cit., p. 79-88, 96-98.

177. Walejko, R. N., J. W. Pendleton, G. Tenpas, R. Rand, and W. Paulson. 1972. "Effect of Snowmobile Traffic on Established Stands of Nonforest Vegetation." Agronomy Abstracts 64:166.

178. Walejko, R. N., J. W. Pendleton, W. H. Paulson, R. E. Rand, G. H. Tenpas, and D. A. Schlough. 1973. "Effect of Snowmobile Traffic on Alfalfa." Journal of Soil and Water Conservation 28(6):272-273.

179. Wanek, Wallace J. 1971a. "Snowmobiling Impacts on Vegetation, Temperatures, and Soil Microbes," in Chubb, 1971 Proceedings . . ., op. cit., p. 116-129.

180. Wanek, Wallace J. 1971b. Untitled presentation within Environmental Panel, in University of Western Ontario, op. cit., p. 111-117.

181. Wanek, Wallace J. 1972. A Continuing Study of the Ecological Impact of Snowmobiling in Northern Minnesota. Final Research Report for 1971-1972. Center for Environmental Studies, Bemidji State College, Bemidji, Minnesota, 22 p.

182. Wanek, Wallace J. 1973a. A Continuing Study of the Ecological Impact of Snowmobiling in Northern Minnesota: Final Research Report for 1972-1973. Center for Environmental Studies, Bemidji State College, Bemidji, Minnesota, 41 p.

183. Wanek, Wallace J. 1973b. "The Ecological Impact of Snowmobiling in Northern Minnesota," in Holecek, 1973 Proceedings . . ., op. cit., p. 57-76.

184. Wanek, Wallace J. 1974. A Continuing Study of the Ecological Impact of Snowmobiling in Northern Minnesota. Final Research Report for 1973-1974. Center for Environmental Studies, Bemidji State College, Bemidji, Minnesota, 54 p.

185. Whittaker, James C. and Dennis S. Wentworth. 1972. Snowmobile Compaction and Forage Grass Yields in Maine. Miscellaneous Report 143, Life Sciences and Agricultural Experiment Station, University of Maine at Orono. The Station, Orono, 3 p.

186. Wilkins, Bruce T. and G. A. Hill. 1971. "A Study of Snowmobilers in Central New York," _in_ Chubb, _Proceedings, 1971 Symposium . . ., op. cit._, p. 46-54.

187. Winona, Inc. 1973. _Motorized Recreation Buying Patterns: A Profile of Recreational Vehicle Ownership and Buying Intentions_. Report prepared for Snowsports Publications, Inc. Winona, Inc., Minneapolis, Minnesota, 49 p.

188. Work, Arch and Gregory Pearson. Undocumented reference _in_ Nelson, Morlan. 1971. "Guilty Until Proven Innocent," article from _Snowmobiling_, January 1971. Article inserted by Senator Bible into U. S. Congress, Senate, Committee on Interior and Insular Affairs, Subcommittee on Parks and Recreation. 1971. _Hearing on Snowmobiles . . ., op. cit._, p. 33-36.

THE LITERATURE OF PLANNING AND MANAGING INTENSIVELY DEVELOPED NATURAL RESOURCE RECREATION SITES

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Abstract.--Literature applying to planning and managing developed recreation sites has been classified by type of decision to which it applies, by whether or not it is the result of research, and by degree of applicability. This classification system is intended to assist managers and planners in assessing and applying knowledge contained in the literature. When applied to 130 publications, the classification system revealed that almost 50 percent of the literature deals with maintenance problems and related information. Other areas apparently require additional research attention.

Additional keywords: Forest recreation sites, site design, campgrounds, research utilization, research priorities, management objectives.

Recent work by a task force which was asked to examine the problems and priorities for research on problems related to recreational use of forest resources in the southern states, indicates that the physical and biological impacts of use on developed sites is still a major concern of forest managers and scientists.[2] A sample of 186 forest recreation managers and administrators and 40 forest recreation scientists in the southern states rated physical and biological impacts fourth among 22 problems identified as important. This finding has particular significance when viewed in the light of recent discouragement of research on this subject area by research administrators, funding agencies, and some scientists. Perhaps a reevaluation of this apparent redirection of recreation research is needed.

It is highly likely that the above rating would be substantiated in other regions of the United States. Continued and often heavy use of the limited number of developed forest recreation sites (primarily campgrounds) continues to pose management problems which result in high costs of maintenance and operation. Sure means for reducing these costs are yet to be found even though a fairly large body of literature is available which deals with establishment and maintenance of developed sites. One of the reasons for the persistence of recreation use impacts as a major problem with developed site recreation is the apparent absence of use of the available literature to any appreciable extent.

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[2] Task Force Report: Forest Resources Research Needs for the Southern Region, June, 1974.

The purposes of this paper are to provide an overview of the state of the art and to develop a decision-making framework which should prove useful in applying the published literature to developed-site establishment and maintenance decisions. A beginning effort is presented at classifying the literature, assembled through a rather comprehensive search, according to applicability to the various categories of decisions which planners and managers must make. There is the likelihood that some published reports have been overlooked in the search process. However, over 200 publications have been assembled and reviewed, and close to 130 of these were applicable to the developed-site management problem.

THE PUBLISHED STATE OF THE ART[3/]

Literature published on the subject of recreation site development and management is quite extensive and in many cases relatively easy to obtain. Yet there is little evidence to suggest that it is being used to any significant extent. Many reasons are likely for this, but the most obvious are the lack of generality of the findings, lack of knowledge that the literature exists, and absence of time or interest by planners and managers for obtaining and reading the published material.

James noted that many of the problems and decisions which managers face are specific to a place and situation. At the same time, the research available through the literature is very specific. Much of it boils down to case-history status. Lack of generality of published research findings means that information is available on many fewer of the factors relevant to specific decisions which managers must make. Therefore, while a particular study may produce results very useful to management of a specific site, it can be of limited or seemingly no use in other management situations.

But when viewed in its entirety, a wealth of information is available in the existing literature. It is unfortunate that it has never been synthesized with emphasis placed on the generality of the information contained. James indicated that four basic subject areas have been reasonably well discussed. These include (1) soils and soils relationships; (2) site planning and design; (3) site vegetation management; and (4) policy, regulatory, and educational matters.

The state of knowledge with respect to soils and soils relationships is at the highest level among the above four subject areas. Soils can now be identified and classified quite accurately. Relatively complete knowledge exists concerning the suitableness of different soils for various forms and intensities of recreational uses. A dominant reason for the problem of

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[3/] This assessment of the state of the art is based in part on the paper entitled "Physical Site Management" prepared by George A. James for the Outdoor Recreation Research Applications Workshop held by the USDA Forest Service at Marquette, Michigan, June 19-21, 1973. Due to the recentness of this paper, a repeat of evaluation of the published literature was unnecessary.

excessive recreation site wear and resultant costs has been the absence of attention to soils. Soils surveys are far enough advanced that very direct information is obtained from them to aid in site-selection, design, and maintenance decisions.

A relatively large amount of literature also has been written which deals with site planning and design. Much of this literature, however, represents the sharing of specific individuals' experiences and/or philosophies and the smaller proportion is based on specific research findings. The research which has been done, however, whether descriptive or experimental, does provide some very good and often generalizable information. For example, Lime[4/] pointed out that research has provided the following information:

a. placement of tables, fireplaces, wells, water hookups, etc., significantly affect site deterioration

b. the hardened surface of the residence space in a site must be large enough to accommodate large tents, multiple tents or trailers, and the multitude of equipment which campers often bring

c. channeling pedestrian or vehicular traffic can substantially reduce site deterioration.

Management of developed site vegetation also has received substantial attention by recreation scientists and other writers. In addition to this, considerable information is available from horticulturists and others. Studies have focused on identification of "durable" vegetation; effects of uncontrolled recreation use; fertilization, watering or other cultural treatments; reasons for abuse of vegetation by recreationists; and on replanting to replace dying or dead vegetation. Proper selection and maintenance of vegetation in the planning phase of recreation site development will eliminate or substantially reduce some of the costly corrective maintenance that will likely be necessary in the long run.

The evaluation of literature dealing with policy, regulatory and educational matters is somewhat less promising than literature applying to the other subject areas. Some scattered research exists pertaining to the effects of signing or other communication devises on behavior and site impact, but the information generated is relatively scattered and lacks unity of purpose. But the increasing emphasis on behavioral research assures us that more is to come and that the information to be provided will likely be more general than much of the previous recreation research has been.

[4/] David L. Lime, "Locating and Designing Campgrounds to Provide a Full Range of Camping Opportunities," in Outdoor Recreation Research: Applying the Results, North Central Experiment Station, USDA Forest Service, General Technical Report NC-9, 1973.

The remainder of this paper is devoted primarily to development of a means for reducing the cost of information retrieval from the literature already available. Realizing that perhaps the most valuable (and thus limiting) resource that a planning or management decision-maker has is his time, it becomes obvious that an easier way is needed for identifying the most relevant literature for a particular problem. In the following pages, planning and managing developed recreation sites is viewed in light of the decisions which must be made. Furthermore, these decisions are viewed as critical to the process of establishing and operating developed sites to the extent that they affect the total costs (current and future, direct and indirect) of supplying this type of recreation service. Minimizing the total costs encountered pursuant to accomplishing predetermined public-use objectives for developed recreation sites is identified as one of the dominant management goals.

A MANAGEMENT GOAL IS COST MINIMIZATION

Most of the emphasis in this paper is on the steps and decisions concerned with recreation site development and maintenance after the public-use objective has been defined. This does not, however, preclude consideration of alternative public use objectives as determinants of total development and operation costs. It is evident that decisions which concern such things as amount, type, and seasonality of public recreation use set the stage for all subsequent decisions and options which the site planner and manager may consider.

Ultimately, the objective for which a site is developed and managed is maximization of the total recreational benefit derivable from the opportunities being provided. This, of course, assumes that the total cost to society of providing these opportunities will not exceed the value of the benefits. In many cases, site planners and designers and management personnel become involved with supply of developed-site recreation after the objective has been defined. At this point, the objective is predetermined, and their focus narrows to accomplishment of two basic, related goals:

(1) sustain the predetermined quality level of experience defined by the objective

(2) minimize the cost of development, operation, and maintenance of the recreation site.

It is the latter of these two goals to which managers usually give the most recognizable attention and with which most of the literature on recreation site design, management, and maintenance has implicitly dealt.

Consideration in this paper of the step of setting or defining public use objectives for developed recreation sites is not in the context of cost minimization. Rather, definition of objectives is considered as it affects the general level of costs to be involved and as it limites or restricts the range of options which may be considered in decision-making relevant to implementing objectives. All subsequent steps involved in the provision of developed-site recreation services, however, are considered from the cost-minimization standpoint.

Development, operation and maintenance costs should be expressed on a per-unit-of-use basis and as present value of all costs discounted over the expected life of site use. Expression of cost in this manner, rather than as a lump sum without regard to units of use, is necessary so that development and operation alternatives can be compared without confounding cost values with the differential effect which these alternatives may have on amount of participation.

Research and other, more general literature has rarely addressed cost minimization as a developed-site management goal. This fact points dramatically to the direction which future research in this problem area should take. Costs must be explicitly recognized and measured, and the factors which affect costs and the manner by which costs are affected must be identified. Existing literature has taken a much more indirect approach.

In developing the decision-making framework for developed-site management and in examining applicable literature, an effort is made to recognize the important decisions necessary at each step of the site establishment/development process and to recognize factors relevant to these decisions. By so doing, it is possible to structure the literature according to applicability to decision-making aimed at minimizing the cost of achieving management objectives for developed site recreation.

THE PROCESS OF ESTABLISHING AND OPERATING DEVELOPED SITES

Including definition of the public use objective(s), there are four basic steps involved in establishing and operating a developed site:

1. Definition of public-use objective(s)
2. Site development planning
3. Site construction
4. Site operation and maintenance.

At each of these steps, a distinct set of decisions is necessary, each requiring costly information describing a critical set of factors which affect the outcome of a decision at its implementation. More specifically, the factors at each decision "level" and the manner by which they are taken into account determine the direct costs of implementing a decision concerning either site development or operation. In addition, the accuracy, completeness, and degree of utilization of available information affect the level of secondary or indirect costs which can be of a long-term nature and which can impact areas or environments other than the developed site itself.

For example, a decision to locate a developed water site on moderately steep slopes so that users can be near the shoreline will have a direct impact on cost of construction (greater terrain modification necessary) and maintenance (increased foot wear on side slopes, greater use overall because of nearness to water, and more soil movement). This set of conditions also is likely to result in secondary costs such as sedimentation in the lake and muddying of the swimming beach. Furthermore, the condition of the site may well deteriorate to a state that maintenance expenditures are no longer reasonable and abandonment of the site and development of a new one become necessary.

In the remainder of this section of the paper, steps in the process of establishing and operating a developed recreation site in a natural setting are considered from the standpoint of the decisions which must be made at each step. The step of defining the public-use management objectives is examined for its effects on the general level of costs and as it affects subsequent decision-making. The remaining steps are discussed from the standpoint of current and future costs of site development and operation which result from choices among alternative courses of action directed toward implementation of defined objectives.

Step 1

Involved with defining public use objectives are four cost-affecting decisions:

a. Amount and type of use

b. Clientele to be served

c. Scale of development

d. "Naturalness" desired.

The first two decisions are closely related, yet they are distinct enough to be given separate consideration. In the assessment of demand for developed-site recreation, information will have been generated indicating the amount of use and type of activities which the public is currently demanding. If reliable information is available, the decisions concerning which activities to provide, the relative emphasis on each, and the amount of use to anticipate are evident. Under realistic conditions, however, specific demand information is not available, and decisions must be made with limited information on current demand and on expected future changes in demand.

Alternative decisions concerning either the activities for which the site will be established or the relative amounts of use by each activity can lead to widely different development and maintenance costs. Misjudgments at this step can lead to extreme under- or over-utilization of the site, or they can lead to uses for which the site is not intended or designed. The cost implications of such misjudgments can be quite serious, and definition of the public recreation use objective of a site development project is a crucial decision affecting all subsequent steps.

Clear recognition of the clientele to be served is equally important to identifying the objective. Whether or not the primary clientele are transient, extended-stay, or day users has an overriding influence on site location, scale and intensiveness of development, maintenance schedules, and use seasons. Also, whether the clientele is principally local or non-local has influence on use-control policies, fee structure, and site location.

Scale of development should also be a major consideration in defining the objective and will affect the per-unit cost of development and operation/maintenance. One large site or several smaller ones are alternatives to be compared. Sites can purposely be made larger than currently needed so that expected future increases in utilization can be accommodated, or so that use pressures can be distributed among different parts of the site at different times.

Along with the above decisions, a clear statement in the objective of degree of "naturalness" in the environment to be created should be made. Costs are directly related to this decision but generally in opposite directions depending on whether establishment or operation/maintenance costs are the focus of attention. Establishment costs are, for the most part, inversely related to naturalness in that much less site modification and facility emplacement are needed. Maintenance costs, however, are likely to be greater if more natural appearance is desired. Heavy use of most sites takes a heavy toll on their "naturalness," and many times frequent and very costly preventive as well as corrective maintenance measures are necessary.

In summary, the public-use objective of a developed site essentially sets the stage for subsequent decisions, costs, and problems. Correct decisions at this step may make the greatest contribution toward cost minimization.

Step 2

Decisions involved with planning site development are guided by the public-use objectives, yet there are many options available at this step. The specification of a plan has a very direct bearing on the costs of establishing the site and on all subsequent costs of operation and maintenance. The general decisions which must be made include:

a. General site location

b. Specific location of site boundaries, units, and service facilities

c. Placement of facilities on individual units

d. Facilities design and materials selection

e. Species, size, and location of vegetative cover.

Decision-making at this step is complex and must be based on accurate information concerning relevant factors and factor interactions.

Selection of general location affects costs because of its relationship to expected levels and kinds of use, to competition with other land uses, and to other recreation opportunities or attractions in the geographic area. Specific factors to consider include location of population centers and major access routes, kind and intensity of surrounding land uses, climate and season lengths, location of unique attractions (scenic or historic), availabilit of consumable water and space, and availability of resources to support off-site activities complementary to the on-site activities. Also to be considere is availability of support services such as stores, sewage treatment, service stations, and management personnel. All of these factors affect travel patterns of users; type and number of service facilities which must be provided; and as stated previously, the level, type, and periodicity of use.

Upon selection of the general site location, the next decision involves exact definition of the site boundaries and the arrangement and spacing of the units and service facilities. Boundaries must be established consistent with the public-use objective and with explicit consideration to internal site characteristics are in turn a function of boundary placement. Soils, slope, overstory and understory vegetation (age, composition, vigor, size), leaf litter depth, elevations of various locations, and existence of unique features all should be considered in boundary placement because of their relevance to unit and facility arrangement and spacing. After boundary establishment, or simultaneously with it, unit and facility placement must be decided, and this will involve additional factors. Included should be local drainage patterns, desired relationships among different anticipated recreational activities, availability of scenic view, desired "common" space, ground water flows, and local wildlife populations. Each of these factors will assume different importance depending on the objective(s). If it specifies a relatively natural environment, then considerable care must be exercised to preserve much of the ecological balance and biotic forms. If less "naturalness" is desired, much less emphasis need be placed on location of units and facilities to make them unobtrusive to the natural system functions. More site modification and planned density will be acceptable in these cases.

Placement of individual unit facilities poses a different set of questions and draws focus on the micro-site factors. The most recognized individual unit is the family camping unit. Facilities usually involve a table, parking space, hookups, and residence and utility space. Micro-site factors affecting placement of these facilities include individual tree locations, slope placement of surrounding units, rock outcroppings, location of internal roads, sun/shade conditions, and drainage patterns. Other factors include intended activity(ies) and clientele and proximity of the unit to support facilities.

The fourth set of decisions concerns the design of the overall service and individual unit facilities including specific attention to construction materials. Design of these facilities gives them specific appearances, directs the way they are used, and determines how much wear or abuse will be encountered. Selection of materials for construction has the same general affect and determines the kind, frequency, and intensity of maintenance and/or replacement that will be required. One of the basic trade-offs to be encountered in making these decisions involves the original cost of materials and assembly and the cost of maintaining (cleaning and repairing) facilities once they are in use.

Factors influencing design decisions should include the type, seasonality, and amount of use anticipated; the desired appearance of the site; kind and level of "conveniences" to be provided; and the availability and prices of materials. As is the case with all of the preceding decisions, factors indicated to be important cannot be considered independently but must be considered simultaneously or in sets because of their inherent interactions.

The final set of decisions relevant to planning site development covers the species, age and size, and location selections for vegetative cover on and surrounding the site. Overstory cover (existing or introduced) for shade, for production of soil organic matter, for aesthetic appearance, and for screening of view where necessary is a very important component of the total site plan. Different species of different sizes present different appearances and have different tolerances to recreation use and the consequences of that use. Age is a determinant of expected longevity of the overstory and the flowering- and fruit-bearing potential which is important to local wildlife populations. The density of overstory cover and its location not only affect apperance and function of the site, but it also determines use patterns and circulation.

Costs associated with understory vegetation (including ground-level vegetation) depend on overstory conditions, species selection and soil conditions. Maintenance of ground cover vegetation can be eliminated by introducing gravel or pavement coverings. But on some sites this would be inconsistent with objectives. In these cases, selection of species, arrangement of facilities, and competition with other understory and overstory vegetation must be evaluated. Understory cover between 3 and 10-feet above ground level provides screening between units and facilities. Where this is desired, multifunctional species acting as wildlife food, flowering shrubs, traffic barriers, and screens can be selected.

Decisions, as discussed above concerning the planning of intensive-use recreation site development, involve a very large number of factors related to geographic location, on-site characteristics, and intended function or use. Many planners and managers have developed skills through practice which enable them to implicitly or explicitly evaluate these factors and their interactions in the planning and design of the site to meet predetermined objectives. Others have either limited or no experience base upon which to base their decisions, and these people will learn how to take proper account of the important factors only by making very costly mistakes. But, even though this group will learn by its mistakes, there will always be a new group entering the professional ranks which must repeat the learning-by-doing process.

Application of the site establishment and maintenance literature can especially be of benefit to this latter group. But continued research emphasizing the full cost implications of site planning decisions will benefit both groups. It is unlikely that even the most experienced professional can be aware of the total cost consequences of the alternative courses of action he has available to him. In this light, research directed toward developing establishment and operation cost functions for sites with various objectives and involving different conditions can be among the more practical and efficient research which recreation scientists may accomplish.

Step 3

At completion of the site development plan the planner/designer, with inputs from management personnel, must supervise implementation of the plan during the construction phase. Decision-making at this step basically involves

a. Sequencing of construction process

b. Technology, labor, and equipment selection and management.

Of all the steps in the site establishment and operation process, site construction and associated costs seem to least fit the conception of a researchable problem. The principal reason for this is that many of the factors which affect construction costs are exogenous to the decision-maker. Available technology, prices, and supplies of materials; availability of skilled and professional personnel; and many other factors are not directly controllable by the planner/construction supervisor. This is especially true if construction is accomplished through contract with an independent construction firm. In this case, even the sequencing of construction steps or phases is partially exogenous.

Because of the general "non-researchableness" of the construction step and the resultant costs and cost determining factors, little attention is or even perhaps should be devoted to them in this paper. It is important, however, to recognize that construction costs can be controlled and that decisions at this step are very important. Most of the information to be used in making construction-specific decisions of necessity will be of local relevance and will consist mostly of the planner's knowledge of local market conditions and materials' availability. More general information should relate to construction technology including data on new machinery and equipment. Although the supply of this information is not a likely role for researchers, it should be made widely available in the form of published documents or other means.

Step 4

Operation and maintenance is the final step in the overall process of providing developed-site recreation opportunities. Like Step 2, which involved planning the site development, there are crucial decisions at this step which have both short-run and long-run cost consequences. The basic decisions include:

1. Policies and control techniques affecting use
2. Maintenance practices
3. Public relations activities
4. Selection and supervision of management personnel.

Policies defined and techniques used to control the way developed sites are used must be synchronized with the decisions made concerning site development. Even the best site plans can be practically nullified if they are not followed with use control techniques administered according to use management policies consistent with the site objectives. Site selection and design will act to direct patterns, types, and intensities of use, but "planned" recreationists' behavior can be substantially modified by use control or management policies and techniques which are inconsistent with the objectives.

For example, many campgrounds are designed for family camping use and are located so as to be accessible to family campers. But these sites may be attractive also to non-family groups whose actions and behavior may greatly conflict with family campers. Such groups can create noise and other undesirable situations which eventually may result in little use of the site by families and in use patterns which seriously impact the site and alter its appearance. Site design and location must be complemented in these situations with adequate policies and techniques which assure achievement of the public-use objectives.

Some of the considerations important in implementing use control include length and timing of season, permitted off-season use, and allowed length of stay by individual parties. Decisions involving these factors may substantially alter the maintenance and operation costs. Other important factors are the fee level, visibility of official personnel, strictness of rules enforcement, and registration procedure or requirement. These affect amount, timing, and types of use and behavior. Because the bodily presence of the recreationists themselves is only a portion of the cause of site impact and resultant costs, the way vehicles and equipment are used must also be considered. Parking of vehicles, use of secondary vehicles such as minibikes, and use of camping equipment (lanterns, tent floors, axes) can especially impact the health and appearance of overstory and understory vegetation and can dramatically alter soil structure and composition.

The second set of decisions in the operation phase of developed-site recreation involves maintenance practices. The manner and intensity by which maintenance is carried out represent costs in themselves. It could be argued that the most effective way to minimize site operation costs is to minimize maintenance expenditures. In fact, this approach seems to be a reality among some management interests. But lack of adequate and timely maintenance may create many more problems and costs than it saves. Site managers have found in most cases that maintenance, following the philosophy that "a stitch in time saves nine," is the most effective approach. Maintenance activities including watering and fertilization of vegetation, soil cultivation, overstory density control, mulching, facilities servicing and repair, and others have a direct impact on a developed site's "health." Maintenance can include vegetation replacement or relocation of facilities to reduce accumulated site wear. Maintenance activity, of course, depends on budget, equipment and personnel availability, but it also depends on the expertise of the site manager(s).

Activities aimed at projecting a particular image of the agency or site or at creating good rapport with clientele and others also may affect operating costs to a very large degree. Signing, advertising (promoting), interpretation programs, and general visitor information services represent means for communicating with users and the local population. What is or is not communicated sets the stage for the kind of use and users and the attitude or knowledgeability persons have of the effects humans can have on a natural environment. This seems particularly true where vandalism is a problem, and in many cases good rapport with local residents seems directly related to absence of a vandalism problem. The personal appearance and attitude of agency representatives who work on the site may be one of the more important factors deciding agency image and rapport.

In this and other respects, selection and supervision of management personnel is extremely important. An effective site operation/management job must depend on the education, in-service training, experience, and other qualities of personnel. Research has done relatively little in this area or in evaluating the effectiveness of supervision. Certainly the amount and kind of supervision given to management personnel is going to affect the level and quality of operation activities and is thus an important determinant of the cost of supplying developed-site recreation opportunity.

APPLICATION OF LITERATURE TO DECISION-MAKING

As a stimulus for its application in arriving at planning and management decisions as discussed in the preceding section, published reports reviewed for this paper have been classified by the step and decision set in site establishment and management to which each applies. These steps and decisions are reviewed below in model form (fig. 1). In some cases, information contained in an article applies to more than one of the steps or decisions. These are listed in more than one place. Literature entries have also been classified on the basis of directness of application, of being a report of research results, and of being an application of general knowledge or philosophy.

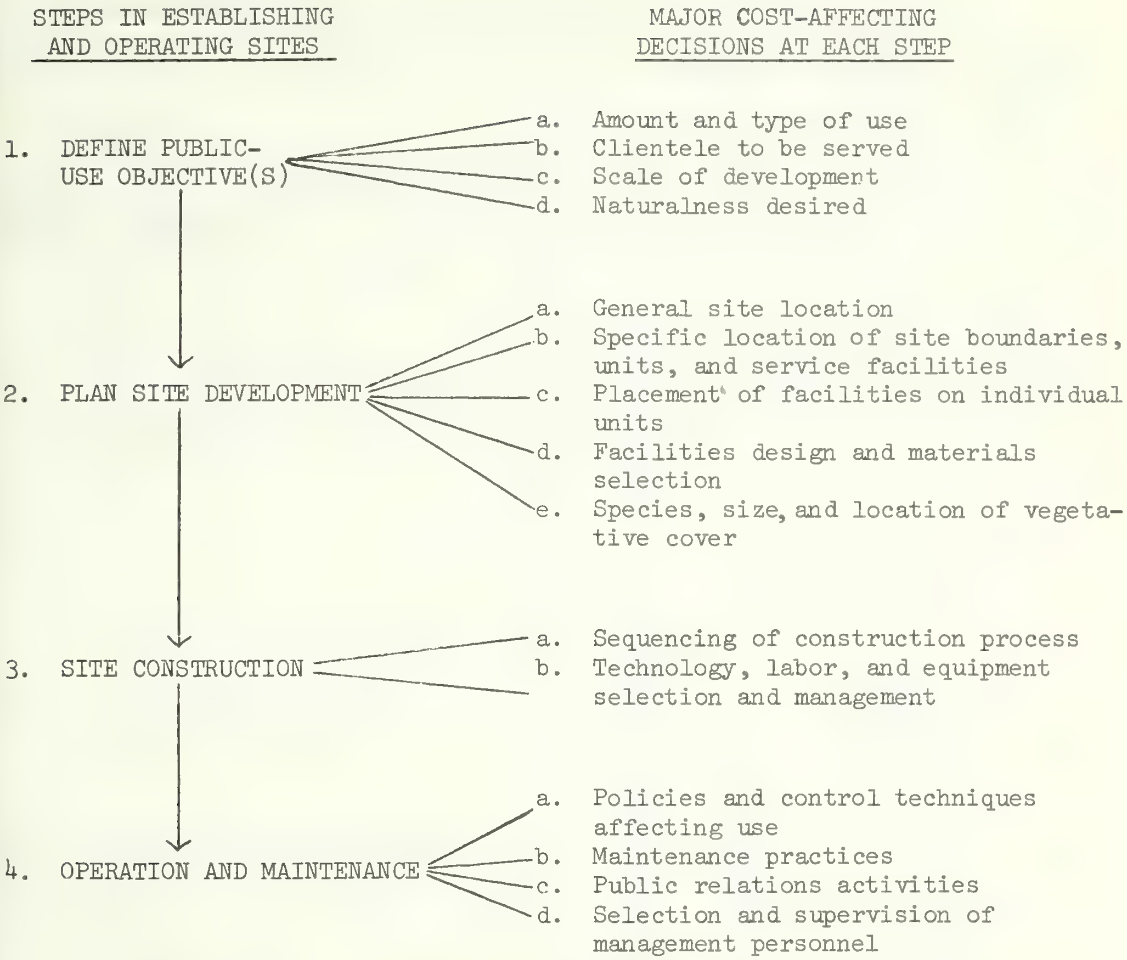
STEPS IN ESTABLISHING AND OPERATING SITES
MAJOR COST-AFFECTING DECISIONS AT EACH STEP
1. DEFINE PUBLIC-USE OBJECTIVE(S)
a. Amount and type of use
b. Clientele to be served
c. Scale of development
d. Naturalness desired
2. PLAN SITE DEVELOPMENT
a. General site location
b. Specific location of site boundaries, units, and service facilities
c. Placement of facilities on individual units
d. Facilities design and materials selection
e. Species, size, and location of vegetative cover
3. SITE CONSTRUCTION
a. Sequencing of construction process
b. Technology, labor, and equipment selection and management
4. OPERATION AND MAINTENANCE
a. Policies and control techniques affecting use
b. Maintenance practices
c. Public relations activities
d. Selection and supervision of management personnel

Figure 1.--Model of decision-making for establishing and operating developed recreation sites.

In the model in fig. 1, steps in establishing and operating sites developed for recreation are numbered as are the cost-affecting decisions (sets) within each step, which are given letter codes. These codes are repeated in succeeding table 1.

In table 1, the right-most column shows the code and description of each decision set except for the decisions involving the construction step of the site development process. This step is not considered for literature classification because of its general non-applicability as a research problem and because of the almost total lack of relevant literature.

Numbers within columns 2, 3, and 4 indicate the numbered order of individual literature entries in the "Listing of Reviewed Literature." Articles are arranged alphabetically, and the last line of each entry in the "Listing" provides information on general source of the information contained as well as the step/decision codes shown in the "Model of Decision-Making." The information source is shown by the first two or four letters in the last line of the entry and refer to the following codes:

RD = Descriptive Research, a report dealing with data collected to describe a problem or situation

RS = Solution-Oriented Research, a report describing a study of means to solve a site development or operation problem

AG = Application of General technical or experience-based knowledge to developed recreation site management or planning

PD = Problem Definition, a discussion or exposition of a development or operation-related problem

UP = User Preferences, an examination of the preferences of users of developed recreation sites

RM = Research Methods, a description or evaluation of a technique or tool for collecting data relevant to developed site establishment or operation

O = Other literature.

The table of literature classification is intended for use by instructors and extension personnel and by planners and managers who are seeking answers or ideas concerning a particular decision within the site development and operation process. It must be emphasized that this is not a complete listing of literature but is a listing of the most available literature. State documents, unpublished reports, theses and dissertations, and some other sources of literature will be examined for inclusion as this work advances. No attempt is made either to provide a comprehensive inventory of literature relevant to defining public-use objectives. As stated at the beginning, this particular step is considered to be beyond the scope of this paper. It is included in the classification table, however, because some of the literature applicable to site planning and operation also applies to definition of objectives.

Table 1.--Classification of research and other literature by degree of applicability to decision-making[a]

Steps and decision sets	Directly applicable literature		Secondarily applicable literature
	(Research)	(Nonresearch)	
1. Define Public-Use Objectives a. Amount and type of use (1.a)	5 122	121	12 59 125 30 62 38 64 42 92 47 113 49
b. Clientele to be served (1.b)	5	91	36 47 117
c. Scale of development (1.c)	66 130		14 41
d. Naturalness desired (1.d)	50 83	42 121	9 49 108 122 12 64 111 125 36 66 113 129 43 93 116
2. Plan Site Development a. General site location (2.a)	5 27 32 63 70	21 25 85 98 114	18 49 96 130 28 60 111 44 65 115 45 66 124 48 91 128
b. Specific location of site boundaries, units, and service facilities (2.b)	15 124 18 130 20 63 69	10 128 22 25 94 110	7 38 54 68 84 100 13 41 55 75 93 104 23 46 60 78 95 107 28 52 62 81 97 108 36 53 65 82 98
c. Placement of facilities on individual units (2.c)	8 18 20 63	25 65 94	5 22 82 110 7 52 83 126 10 53 100 13 78 107

Table 1.--(continued)

	(Research)	(Nonresearch)	
d. Facilities design and materials selection (2.d)	14 63 86	4 25 127	2 18 93 116
e. Species, size, and location of vegetative cover (2.e)	3 29 57 18 50 63 19 51 75 20 52 79 100 105 120	24 104 73 126 95 99	9 56 102 11 61 107 13 77 110 41 82 118 53 88 123 55 96
3. Site Construction	Not Applicable	Not Applicable	Not Applicable
4. Operation and Maintenance a. Policies and control techniques affecting use (4.a)	14 16 37 58 71 80 122	9 67 102 115 125	4 62 13 64 29 84 38 96 42 107 48 113 53 117
b. Maintenance practices (4.b)	6 18 46 7 19 61 8 32 79 17 37 105	4 35 73 99 22 40 78 102 25 53 87 104 31 72 88 126 127	2 23 52 69 81 103 11 3 29 54 74 82 106 12 10 33 56 75 90 110 12 13 34 57 76 95 112 15 39 68 77 101 115
c. Public relations activities (4.c)	71 123	89	4 49 66 107 125 6 58 67 113 16 62 82 115 47 64 83 122
d. Selection and supervision of management personnel (4.d)		26	

[a] Numbers within this table refer to the numbered articles in the References section.

In reviewing literature related to a particular decision problem, it is suggested that articles classified as "directly applicable" be sought first. In addition, the directly applicable literature is subdivided into "research" and "non-research" categories. It is suggested that the research literature be given higher priority than the non-research literature. Useful information and ideas are contained in all the listed articles, however, and secondarily-applicable literature should be given attention also.

FURTHER RESEARCH AND LITERATURE APPLICATION WORK NEEDED

A very large amount of information is contained in the many published works which deal with recreation site development and operation. Classifying existing literature according to specific decision sets should promote more use of the information within. But at the same time it points out gaps or voids where little has been written and especially where researchers have not ventured. The table of classification shown on preceding pages indicates that most of the attention has been given to maintenance practices or methods. Almost 50 percent of all the published articles reviewed for this paper, and more specifically 20 percent of the research articles, deal with maintenance-related problems and related information. Next greatest attention (about 30 percent of the articles) is on the location of site boundaries, units, and service facilities. The third-ranking decision set concerns species, size and location of on-site vegetative cover.

Measured in terms of percentage of research articles, however, a different picture is presented in that almost one-fourth of the published research results deals with on-site vegetation. The biological-educational background of many of the recreation scientists (especially during the 1960's) explains much of this emphasis. Notably lacking in the literature is research emphasis on decisions involving (1) general site location, (2) placement or arrangement of facilities on individual user units within the site, (3) design and materials selection for site facilities, (4) policies and control techniques affecting amount, type, and periodicity of recreation use, (5) the effectiveness and impact of public relations activities, and (6) selection and supervision of management personnel.

Future research dealing with developed sites should give explicit recognition to the cost implications of alternative courses of action in the establishment and operation process and particularly to the six areas listed above. Given a predetermined budget and objective, planners and managers need information directly relevant to minimizing the cost of providing developed site opportunity so that maximum output can be realized for each dollar of expenditure. Development of explicit cost functions are thus called for. A serious limitation on this research has been the availability of cost data. But the impact of this limitation can be reduced by greater efforts and willingness on the part of planners and managers to keep detailed cost data through improved cost accounting procedures. Therefore, the research needed concerns development of comprehensive cost functions which will enable better prediction of the consequences of alternative courses of action and better evaluation of their effectiveness. Research administrators and funding agencies should discourage further attempts to describe the problem. Descriptive studies have already adequately exposed its seriousness. Our emphasis needs to be on solution-oriented research and particularly on studies which examine the costs of alternative solutions.

Further encouragement of application of existing literature is also needed. A great deal of knowledge implicitly addressing the costs and benefits of alternative courses of developmental and operational actions is already available. But a more effective system for disseminating this information is required if it is to be utilized. The next step of the classification process started here should be to examine what the literature has to offer concerning specific information needed for making "good" judgments concerning each of the decisions earlier identified. Planned work in this area will involve classification with respect to decision application of each finding, conclusion, or implication in available reports (published and unpublished) as they relate specifically to a needed bit of information. Automatic data processing will be required for such a system, and this will enable rapid retrieval of information in response to a quite specific request.

Such a system may have its greatest impact on future research because it will focus attention on what we do not know as well as on what we do know. It will also encourage much more specific research rather than general research which addresses no specific problem. Many of the papers reviewed had application to three or four different categories of decisions, and as a result the information was usually incomplete for any one category. More specifically focused research and research reports should greatly enhance their use and applicability.

LISTING OF REVIEWED LITERATURE[5]

1. Badaracco, Robert J. 1974. A guide to literature retrieval in outdoor recreation. Coll. of Forest, Wildlife and Range Sci., Univ. of Idaho, Moscow, Id.
(O)

2. Barton, Michael A. 1969. Water pollution in remote recreational areas. J. of Soil and Water Conserv. 24(4):132-134.
(PD--2.d.2/4.b.2)

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[5] The letter and number coding below each cited publication refers to the literature categories and level of decision within the "Model of Decision-Making". For example, the coding below article number 2 by Barton is (PD--2.d.2/4.b.2). PD refers to the "Problem Definition" category and 2.d.2 and 4.b.2 refer to decisions 2.d and 4.b in the Model. The 2 at the end of each of these codes refers to the level of applicability of the literature. A 1 indicates direct applicability and a 2 indicates indirect or secondary applicability.

3. Bates, G. H. 1935. The vegetation of footpaths, sidewalks, cart-tracks and gateways. J. of Ecol. 23:470-487.
(RD--2.e.1/4.b.2)

4. Beard, Daniel B. 1965. Meeting park maintenance problems. Park Practice Guideline, May:55-59.
(AG--2.d.1/4.a.2/4.b.1/4.c.2)

5. Beardsley, Wendell. 1967. Cost implications of camper and campground characteristics in central Colorado. USDA Forest Serv. Res. Note RM-86. Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colo.
(RS--1.a.1/1.b.1/2.a.1/2.c.2)

6. __________, and Herrington, Roscoe B. 1971. Economics and management implications of campground irrigation--a case study. USDA Forest Serv. Res. Note INT-129. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(RS--4.b.1/4.c.2)

7. __________, __________, and Wagar, J. Alan. 1974. How to rehabilitate a heavily used campground without stopping visitor use. J. of For. 72: 279-281.
(RS--2.b.2/2.c.2/4.b.1)

8. __________, and Wagar, J. Alan. 1971. Vegetation management on a forested recreation site. J. of For. 69(10):728-731.
(RS--2.c.1/2.e.2/4.b.1)

9. Bevins, Malcolm I. 1971. Campground planning for the 1970's. Park Practice Trends 8:21-24.
(AG--1.d.2/4.a.1)

10. Bohart, Charles V. 1968. Good recreation area design helps prevent site deterioration. J. of Soil and Water Cons. 23(1):21-22.
(AG--2.b.1/2.c.2/4.b.2)

11. Bonnor, G. M. 1967. Estimation of ground canopy density from ground measurements. J. of For. 65:544-547.
(RM--2.e.2)

12. Brewer, Durward, and Gillespie, Glenn A. 1967. Estimating satisfaction levels of outdoor recreationists. J. of Soil and Water Cons. 22:248-249.
(AG--1.a.2/1.d.2)

13. Burden, R. F., and Randerson, P. F. 1972. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. J. of Appl. Ecol. 9(2):439-457.
(RD--2.b.2/2.c.2/2.e.2/4.a.2/4.b.2)

14. Campground and RV Park Management. 1972. Campers polled on parks. July issue.
(RD, UP--1.c.2/2.d.1/4.a.1)

15. Cieslinski, Thomas J., and Wagar, J. Alan. 1970. Predicting the durability of forest recreation sites in northern Utah--preliminary results. USDA For. Serv. Res. Note INT-117. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(RS--2.b.1/4.b.2)

16. Clark, Roger N., Hendee, John C., and Campbell, Frederick L. 1971. Depreciative behavior in forest campgrounds: an exploratory study. USDA For. Serv. Res. Note PNW-161. Pac. Northwest For. and Range Exp. Stn., Seattle, Wash.
(RD--4.a.1/4.c.2)

17. Cordell, Harold K., and Talhelm, Daniel R. 1969. Planting grass appears impractical for improving deteriorated recreation sites. USDA For. Serv. Res. Note SE-105. Southeastern For. Exp. Stn., Asheville, N. C.
(RS--4.b.1)

18. __________, and Sykes, Clinton K. 1969. User preferences for developed-site camping. USDA For. Serv. Res. Note SE-122. Southeastern For. Exp. Stn., Asheville, N. C.
(RD, UP--2.a.2/2.b.1/2.c.1/2.d.2/2.e.1)

19. __________, and James, George A. 1971. Supplementing vegetation on southern Appalachian recreation sites with small trees and shrubs. J. of Soil and Water Cons. 26:235-238.
(RS--2.e.1/4.b.1)

20. __________, and __________. 1972. Visitors' preferences for certain physical characteristics of developed campsites. USDA For. Serv. Res. Pap. SE-100. Southeastern For. Exp. Stn., Asheville, N. C.
(UP, RS--2.b.1/2.c.1/2.e.1)

21. Cressman, D. R., and Hoffman, D. W. 1967. Classifying land for recreation. Soil Cons. Soc. of Amer. Proc. Guelph, Ontario: Dept. of Soil Sci., Univ. of Guelph, p. 197-200.
(AG--2.a.1)

22. Densmore, Jack, and Dahlstrand, Nils P. 1965. Erosion control on recreation land. J. of Soil and Water Cons. 20:261-262.
(AG--2.b.1/2.c.2/4.b.1)

23. Dotzenko, A. D., Papamichos, N. T., and Romine, D. S. 1967. Effect of recreational use on soil and moisture conditions in Rocky Mountain National Park. J. of Soil and Water Cons. 22:196-197.
(RD--2.b.2/4.b.2)

24. Douglas, Donald S. 1965. Conservation plants for new land uses. Soil Cons. August:3-5.
(AG--2.e.1)

25. Duncan, D. P. 1963. How to avoid picnic area deterioration. Park Practice Guideline, Nov.:67-71.
(AG--2.a.1/2.b.1/2.c.1/2.d.1/4.b.1)

26. __________. 1971. Managing the forest environment: role of the professional. J. of For. 69(1):8-11.
(AG--4.d.1)

27. Dyer, A. Allen, and Whaley, R. S. 1967. Predicting use of recreation sites. Utah Ag. Exp. Stn. Bull. 477. Utah State Univ., Logan, Ut.
(RS--2.a.1)

28. __________. 1969. Recreation site selection: a conceptual approach. Inst. for the Study of Outdoor Rec. and Tour., Utah State Univ., Logan, Ut.
(AG--2.a.2/2.b.2)

29. Echelberger, Herbert E. 1971. Vegetative changes at Adirondack Campgrounds 1964 to 1969. USDA For. Serv. Res. Note NE-142. Northeastern For. Exp. Stn., Upper Darby, Pa.
(RD--2.e.1/4.a.2/4.b.2)

30. Fisher, Anthony C., and Krutilla, John V. 1972. Determination of optimal capacity of resource-based recreation facilities. Nat. Res. J. July: 417-444.
(AG--1.a.2)

31. Forest Farmers Association. 1968. Insects attacking forest trees in the South. For. Farm. 27:36-51.
(AG--4.b.1)

32. Frissell, Sidney S., Jr., and Duncan, Donald P. 1965. Campsite preference and deterioration in the Quetico-Superior canoe country. J. of For. 63: 256-260.
(RD--2.a.1/4.b.1)

33. Garrison, George A. 1949. Uses and modifications for the "moosehorn" crown closure estimator. J. of For. 47:733-735.
(RM--4.b.2)

34. Getz, Lowell L. 1968. A method for measuring light intensity under dense vegetation. Ecology 49(6):1168-1169.
(RM--4.b.2)

35. Gibbs, L. C. 1964. Fertilizing ornamental shrubs and small trees. Park Practice Guideline 12-1:49-50.
(AG--4.b.1)

36. Gift, Robert F., and Muench, John. 1965. Factors which might affect the establishment of standardized campgrounds. (Unpublished report from Univ. of Penn.)
(UP--1.b.2/1.d.2/2.b.2)

37. Gilbert, C. Gorman, Peterson, G. L., and Lime, D. W. 1972. Toward a model of travel behavior in the boundary waters canoe area. Env. and Behav. 4(2): 131-157.
(RS--2.a.1/2.b.2/4.a.1/4.b.1)

38. Hammon, Gordon A., Cordell, Harold K. et al. 1974. Capacity of water-based recreation systems--Part II: a systems approach to capacity analysis. Water Resources Res. Inst. of the Univ. of N. C., Raleigh, N. C.
(AG--1.a.2/2.b.2/4.a.2)

39. Hansen, Henry L. 1967. Ecological and silvicultural research on forest recreational areas. Minnesota Sci. 23(3):42-43.
(AG--4.b.2)

40. Harper, John C., II. 1964. Turfgrass fertilization of park areas. Park Practice Guideline, June:41-44.
(AG--4.b.1)

41. Held, R. Burnell. 1969. A study to develop practical techniques for determining the carrying capacity of natural areas in the national park system. Colo. State Univ., Center for Res. and Educ., Fort Collins, Colo.
(RS--1.c.2/2.b.2/2.e.2)

42. Hendee, John C., and Campbell, Frederick L. 1969. Social aspects of outdoor recreation--the developed campground. Trends, October:13-16.
(PD--1.a.2/1.d.1/4.a.2)

43. __________. 1970. Recreational values, use and management of natural areas. 1970 Symp. Proc. of the Northwest Sci. Assoc.
(O--1.d.2)

44. __________, and Stankey, George H. 1973. Biocentricity in wilderness management. Bioscience 23:535-538.
(O--2.a.2)

45. Herrington, Roscoe B., and Tocher, S. Ross. 1967. Aerial photo techniques for a recreation inventory of mountain lakes and streams. USDA For. Serv. Res. Pap. INT-37. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(AG--2.a.2)

46. __________, and Beardsley, Wendell G. 1970. Improvement and maintenance of campground vegetation in central Idaho. USDA For. Serv. Res. Pap. INT-87. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(RS--2.b.2/4.b.1)

47. Hopkins, Walter S. 1965. Outdoor recreation on small woodlands. USDA For. Serv., Wash., D. C.
(AG--1.a.2/1.b.2/4.c.2)

48. Houston, Douglas B. 1971. Ecosystems of national parks. Science 172:648-651.
(PD--2.a.2/4.a.2)

49. Hutchinson, S. Blair. 1962. Recreation opportunities and problems in the national forests of the northern and intermountain regions. USDA For. Serv. Res. Pap. 66. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(PD--1.a.2/1.d.2/2.a.2/4.c.2)

50. James, George A., and Cordell, Harold K. 1970. Importance of shading to visitors selecting a campsite at Indian Boundary Campground in Tennessee. USDA For. Serv. Res. Note SE-130. Southeastern For. Exp. Stn., Asheville, N. C.
(RD--1.d.1/2.e.1)

51. __________, and Cottrell, Richard L. 1968. To cut or not to cut. J. of For. 66:57-59.
(RM--2.e.1)

52. __________, and Ripley, Thomas H. 1963. Overuse: a threat to our developed recreation areas. Amer. Rec. J. 4:5-6.
(RD--2.b.2/2.c.2/2.e.1/4.b.2)

53. __________. 1973. Physical site management. In Outdoor Recreation Research: applying the results. USDA For. Serv. Gen. Tech. Rep. NC-9. North Central For. Exp. Stn., St. Paul, Minn.
(AG--2.b.2/2.c.2/2.e.2/4.a.2/4.b.1)

54. Jemison, George M. 1966. Impacts of recreation on the ecology of temperate North American forests. Paper presented at the IUCN 10th Technical Meeting, Lucerne.
(PD--2.b.2/4.b.2)

55. LaPage, Wilbur F. 1962. Recreation and the forest site. J. of For. 60: 319-321.
(RD--2.b.2/2.e.2)

56. __________. 1964. Under the camper's feet. Amer. Rec. J., p. 103-104.
(RD--2.e.2/4.b.2)

57. __________. 1967. Some observations on campground trampling and ground cover response. USDA For. Serv. Res. Pap. NE-68. Northeastern For. Exp. Stn., Upper Darby, Pa.
(RD--2.e.1/4.b.2)

58. __________. 1968. The role of fees in campers' decisions. USDA For. Serv. Res. Pap. NE-118. Northeastern For. Exp. Stn., Upper Darby, Pa.
(RD--4.a.1/4.c.2)

59. __________. 1970. The mythology of outdoor recreation planning. So. Lumberman 221:118-121.
(O--1.a.2)

60. Leopold, Luna B., Clarke, Frank E., Hanshaw, Bruce B., and Balsley, James R. 1971. Procedure for evaluating environmental impact. US Geological Survey Circular 645, Wash., D. C.
(AG--2.a.2/2.b.2)

61. Lightle, Paul C., and Hawksworth, Frank G. 1973. Control of dwarf mistletoe in a heavily used ponderosa pine recreation forest: Grand Canyon, Arizona. USDA For. Serv. Res. Pap. RM-106. Rocky Mountain For. and Range Exp. Stn., Fort Collins, Colo.
(RS--2.e.2/4.b.1)

62. Lime, David W., and Stankey, George H. 1971. Carrying capacity: maintaining outdoor recreation quality. In Recreation Symposium Proc., p. 174-184. Northeastern For. Exp. Stn., USDA For. Serv.
(AG--1.a.2/2.b.2/4.a.2/4.c.2)

63. __________. 1971. Factors influencing campground use in the Superior National Forest of Minnesota. USDA For. Serv. Res. Pap. NC-60. North Central For. Exp. Stn., St. Paul, Minn.
(RS--2.a.1/2.b.1/2.c.1/2.d.1/2.e.1)

64. __________. 1972. Large groups in the boundary waters canoe area--their numbers, characteristics, and impact. USDA For. Serv. Res. Note NC-142. North Central For. Exp. Stn. St. Paul, Minn.
(RD--1.a.2/1.d.2/4.a.2/4.c.2)

65. __________. 1973. Locating and designing campgrounds to provide a full range of camping opportunities. In Outdoor Recreation Research: Applying the Results. USDA For. Serv. Gen. Tech. Rep. NC-9. North Central For. Exp. Stn., St. Paul, Minn.
(AG--2.a.2/2.b.2/2.c.1)

66. Lucas, Robert C. 1970. User evaluation of campgrounds on two Michigan national forests. USDA For. Serv. Res. Pap. NC-44. North Central For. Exp. Stn., St. Paul, Minn.
(RD, UP--1.c.1/1.d.2/2.a.2/4.c.2)

67. __________, and Hendee, John C. 1973. Mandatory wilderness permits: a necessary management tool. J. of For. 71.
(O--4.a.1/4.c.2)

68. Lull, Howard W. 1959. Soil compaction on forest and range lands. USDA For. Serv. Misc. Pub. No. 768. Wash., D. C.
(AG--2.b.2/4.b.2)

69. Lutz, H. J. 1945. Soil conditions of picnic grounds in public forest parks. J. of For. 43:121-127.
(RD--2.b.1/4.b.2)

70. McCool, Stephen F., Merriam, Lawrence C., Jr., Cushwa, Charles T. 1969. The condition of wilderness campsites in the boundary waters canoe area. School of For., Univ. of Minnesota, St. Paul, Minn.
(RD, PD--2.a.1)

71. McCurdy, Dwight R. 1970. Recreationists' attitudes toward user fees: management implications. J. of For. 68:645-646.
(UP, RD--4.a.1/4.c.1)

72. McIntyre, Arthur C. 1950. Woodchips for "overgrazed" recreational areas. J. of For. 48(10).
(AG--4.b.1)

73. Madison, John. 1971. Turf management interactions. Parks and Rec. 6:32-35.
(AG--2.e.1/4.b.1)

74. Magill, Arthur W. 1963. Evaluating ecological trends on campgrounds. USDA For. Serv. Res. Note PSW-N16. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RD--4.b.2)

75. __________, and Nord, Eamor C. 1963. An evaluation of campground conditions and needs for research. USDA For. Serv. Res. Note PSW-4. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RD--2.b.2/2.e.1/4.b.2)

76. __________, and Twiss, R. H. 1965. A guide for recording esthetic and biologic changes with photographs. USDA For. Serv. Res. Note PSW-77. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RM--4.b.2)

77. __________, and Leiser, Andrew T. 1967. New help for worn out campgrounds. USDA For. Serv. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RS--2.e.2/4.b.2)

78. __________. 1970. Five California campgrounds conditions improve after 5 years' recreational use. USDA For. Serv. Res. Pap. PSW-62. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RD--2.b.2/2.c.2/4.b.1)

79. __________, and Leiser, Andrew T. 1972. Growing plants on view landscapes and recreation areas. Guideline 2:57-61.
(RS--2.e.1/4.b.1)

80. Manthy, Robert S., and Tucker, Thomas L. 1972. Supply costs for public forest land recreation. Ag. Exp. Stn. Res. Rep. 158. Michigan State Univ., East Lansing, Mich.
(RD--4.a.1)

81. Merriam, L. C, Jr., Goeckerman, Kent, Bloemendal, J. A., and Costello, T. M. 1971. A progress report on the condition of newly established campsites in the boundary waters canoe area. Univ. of Minnesota For. Res. Note No. 232. College of Forestry, Univ. of Minnesota, St. Paul, Minn.
(RD--2.b.2/4.b.2)

82. __________, Smith, C. K., et al. 1973. Newly developed campsites in the boundary waters canoe area. Ag. Exp. Stn., Univ. of Minnesota, St. Paul, Minn.
(RD--2.b.2/2.c.2/2.e.2/4.b.2/4.c.2)

83. __________, Mills, A. S., Ramsey, C. E., West, P. C., Brown, T. L., and Wald, K. D. 1973. The camper in Minnesota state parks and forests--some insights on use and management from a five-year study. Ag. Exp. Stn. Bull. 510 - For. Ser. 12. Univ. of Minnesota, St. Paul, Minn.
(RD, UP--1.c.2/1.d.1/4.c.2)

84. Michaud, Howard H. 1966. Ecological impact and patterns of use of American forest recreation areas. Purdue Univ., Lafayette, Ind.
(AG--2.b.2/4.a.2)

85. Montville, F. E. 1964. Campground development. Maine Univ. Ag. Ext. Cir. 385.
(AG--2.a.1)

86. Moore, William F., and Page, Rufus H. 1964. Study of the comparative durability and user preference of concrete and wooden picnic tables. Southeastern For. Exp. Stn., Asheville, N. C.
(RD, UP--2.d.1)

87. Musser, H. B. 1961. Topdressing mixtures for turfgrass areas. Park Practice Guidelines 3-1:17-19.
(AG--4.b.1)

88. Neff, Paul E. 1965. Applied silviculture in managing outdoor recreation sites. Proceedings of the Society of American Foresters, p. 34-35. Detroit, Michigan.
(AG--2.e.2/4.b.1)

89. Noble, N. W. 1968. Mess at Miracle Rock. Our Public Lands 18:4-5.
(PD--4.c.1)

90. Nord, Eamor C. Vegetational changes on recreation sites in national forest campgrounds. 14th Annual Univ. of California Ext. For. Field School
(RD--4.b.2)

91. O'Brien, Robert R. 1969. Concentration--the key to quality in outdoor recreation. Paper presented to the annual meeting of the Association of Pacific Coast Geographers, San Fernando, California.
(AG, PD--1.b.1/2.a.2/2.b.2)

92. O'Connell, Paul F., and Boster, Ron S. 1974. Demands on national forests require coordinated planning. Arizona Rev. 23(2):1-7.
(AG--1.a.2)

93. Ohmann, Lewis F. 1973. Ecological carrying capacity. In Outdoor Recreation Research: Applying the Results. USDA For. Serv. Gen. Tech. Rep. NC-9, p. 24-28. North Central For. Exp. Stn., St. Paul, Minn.
(AG--1.d.2/2.b.2/2.d.2)

94. Orr, Howard R. 1971. Design and layout of recreation facilities. In Recreation Symposium Proceedings. USDA For. Serv. Pub., p. 23-27. Northeastern For. Exp. Stn., Upper Darby, Pa.
(AG--2.b.1/2.c.1)

95. Paine, Lee A. 1966. Accidents caused by hazardous trees on California forest recreation sites. USDA For. Serv. Res. Note PSW-133. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(PD--2.b.2/2.e.1/4.b.2)

96. __________. 1966. Butt rot defect and potential hazard in lodgepole pine on selected California recreational areas. USDA For. Serv. Res. Note PSW-106. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(RD--2.a.2/2.e.1/4.a.2)

97. Parke, W. N. 1952. Proper planning of campgrounds and picnic areas. J. of For. 50:595-600.
(AG--2.b.2)

98. Partain, L. E. 1966. Use of soils knowledge in recreation area planning. Virginia Polytechnical Inst. Ext. Bull. 301, p. 180-184. Blacksburg, Va.
(AG--2.a.1/2.b.2)

99. Ripley, Thomas H. 1962. Tree and shrub response to recreation use. USDA For. Serv. Res. Note 171. Southeastern For. Exp. Stn., Asheville, N. C.
(RS--2.e.1/4.b.2)

100. _________. 1962. Recreation impact on southern Appalachian campgrounds and picnic sites. USDA For. Serv. Res. Pap. No. 153. Southeastern For. Exp. Stn., Asheville, N. C.
(RS--2.b.2/2.c.2/2.e.1)

101. _________, Johnson, Frank M., and Moore, William H. 1963. A modification of the line intercept method for sampling understory vegetation. J. of Range Manage. 16(1):9-11.
(RM--4.b.2)

102. _________. 1965. Rehabilitation of forest recreation sites. Proceedings, Society of American Foresters, Detroit, Mich.
(AG--2.e.2/4.a.1/4.b.1)

103. Robinson, Mark W. 1947. An instrument to measure forest crown cover. The For. Chron. 23(3):222-225.
(RM--4.b.2)

104. Rudolf, Paul O. 1967. Silviculture for recreation area management. J. of For. 65:385-390.
(AG--2.b.2/2.e.1/4.b.1)

105. Settergren, C. D., and Cole, D. M. 1970. Recreation effects on soil and vegetation in the Missouri Ozarks. J. of For. 68(4):231-233.
(RD--2.e.1/4.b.1)

106. Severson, K. E., and Gartner, F. R. 1968. A permanent plot for measurement of vegetation change. J. of Range Manage. 2:111-112.
(RM--4.b.2)

107. Shafer, Elwood L. 1964. The photo-choice method for recreation research. USDA For. Serv. Res. Pap. NE-29. Northeastern For. Exp. Stn., Upper Darby, Pa.
(RM--2.b.2/2.c.2/2.e.2/4.c.2)

108. Smith, Robert Leo. 1967. Impact of recreation on natural areas. Sci., p. 10-12, 16.
(AG--1.d.2/2.b.2/4.a.2)

109. Stankey, George H., and Lime, David W. 1973. Recreational carrying capacity: an annotated bibliography. USDA For. Serv. Gen. Tech. Rep. INT-3. Intermountain For. and Range Exp. Stn., Ogden, Ut.
(0)

110. Stevens, Mervin E. 1966. Soil surveys as applied to recreation site planning. J. of For. 64:314-316.
(AG--2.b.1/2.c.2/2.e.2/4.b.2)

111. Stone, Edward H. 1967. Forestry and natural beauty. Soil Conservation Society of American Proceedings, p. 174-177.

112. Strickler, Gerald S. 1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. USDA For. Serv. Res. Note 180. Pac. Northwest For. and Range Exp. Stn., Portland, Ore.
(RM--4.b.2)

113. Sudia, Theodore W., and Simpson, James M. 1973. Recreational carrying capacity of the national parks. Parks Practice Guideline 3(3):25-34.
(AG--1.a.2/1.d.2/4.a.2/4.c.2)

114. Taylor, Gordon D., and Thomson, Clark W. 1966. Proposed methodology for an inventory and classification of land for recreational use. For. Chron. 42:153-159.
(AG--2.a.1)

115. Tocher, S. Ross, Wagar, J. Alan, and Hunt, John D. 1965. Sound management prevents worn out recreation sites. Parks and Rec. 48(3):151-153.
(AG--2.a.2/4.a.1/4.b.2/4.c.2)

116. Twiss, Robert H., and Litton, R. Burton. 1966. Research on forest environmental design. In Proceedings, Soc. of Amer. For., p. 209-210. Seattle, Wash.
(O--1.d.2/2.d.2)

117. Tyre, Gary L., and James, George A. 1971. Length and rate of individual participation in various activities on recreation sites and areas. USDA For. Serv. Res. Note SE-161. Southeastern For. Exp. Stn., Asheville, N. C.
(RD--1.b.2/4.a.2)

118. Tyul'panov, N. M. 1968. Management of forest parks (translated by N. Steigman). Ismel Program for Scientific Translations. Jerusalem, Israel.
(AG--2.e.2)

119. U. S. Department of Agriculture. 1962. Understanding soil compaction. Ag. Res. 11:7.
(RD--4.b.2)

120. U. S. Department of Agriculture. 1963. Turf--the rug for recreation. Ag. Res. 12:13.
(RS--2.e.1/4.b.2)

121. Wagar, J. Alan. 1959. How to predict which vegetated areas will stand up best under active recreation. Amer. Rec. J. 1(7):20-21.
(RS--2.a.2/2.b.1)

122. __________. 1963. Campgrounds for many tastes. USDA For. Serv. Res. Pap. INT-6. Intermountain For. and Range Exp. Stn.
(AG--1.a.1/1.d.1)

123. __________. 1964. The carrying capacity of wild lands for recreation. For Sci. Mon. 7. Society of Amer. For., Wash., D. C.
(RS--1.a.1/1.d.2/4.a.1/4.c.2)

124. __________. 1965. Cultural treatment of vegetation on recreation sites. 1965 Proceedings of the Society for Amer. For., p. 37-39. Detroit, Mich.
(RS--2.e.2/4.c.1)

125. __________. 1974. Recreational carrying capacity reconsidered. J. of For. 72:274-278.

126. Wagener, Willis W. 1963. Judging hazard from native trees in California recreational areas. USDA For. Serv. Res. Pap. PSW-P1. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.
(AG--2.c.2/2.e.1/4.b.1)

127. Walker, Lawrence C. 1964. Fertilizing shade and forest trees in parks. Park Practice Guideline 11-1:45-47.
(AG--2.d.1/4.b.1)

128. White, William C. 1964. Soil tests for better park grounds. Park Practice Guideline 9-1:39-44.
(AG--2.a.2/2.b.1/4.b.2)

129. Whytehead, R. M. 1960. Development of land for recreational purposes. Chartered Land Agent's Soc. J. 59:428-432.
(AG--1.d.2)

130. Young, R. A. 1972. Camper preferences in two southern Illinois campgrounds. For. Resources Rep. No. 72-3, Ag. Exp. Stn., Univ. of Ill., Urbana-Champaig Ill.
(RD, UP--1.c.1/2.a.2/2.b.1)

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SOUTHERN FORESTRY SMOKE MANAGEMENT GUIDEBOOK

DEDICATION

The staff of the Southern Forest Fire Laboratory respectfully dedicates this work to the memory of Robert W. Cooper whose guidance and inspiration long helped to bring science to the art of prescribed burning in the South.

HOW THIS BOOK WAS WRITTEN

Contributions from many scientists were required to complete this Guidebook. These contributors are listed as authors of the individual Chapters, and they take sole responsibility for technical content. Advice on overall content and applicability for users was provided by a group of compilers. The senior compiler worked directly with the authors to achieve a team product.

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Additional contributions in the form of technical reviews and assistance have helped to shape the final result. These are acknowledged in a Special Acknowledgments Section following the Glossary.

USDA Forest Service General Technical Report SE-10
December 1976

SOUTHERN FORESTRY SMOKE MANAGEMENT GUIDEBOOK

by
Southern Forest Fire Laboratory Personnel
Southeastern Forest Experiment Station

U.S. Department of Agriculture-Forest Service
Southeastern Forest Experiment Station
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ABSTRACT

A system for predicting and modifying smoke concentrations from prescription fires is introduced. While limited to particulate matter and the more typical southern fuels, the system is for both simple and complex applications. Forestry smoke constituents, variables affecting smoke production and dispersion, and new methods for estimating available fuel are presented.

KEYWORDS: Air quality, pollution, prescribed burning, smoke management, particulate matter, smoke concentrations, emission factors, components of forestry smoke, fuel loading.

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PERSPECTIVES

The air we breathe is essential to our lives and well-being. Forests are also important to our well-being. This Guidebook was prepared because the fires used in forest management can temporarily reduce air quality. Possible air quality impacts are discussed in detail, and ways are suggested to minimize unwanted atmospheric consequences when using fire in the forests. Procedures and suggestions to follow should be viewed as an opportunity to apply the best available knowledge, consistent with current need. In some locales, this need may be for use of only the more simple procedures. Complex air quality problems in other locales are likely to call for application of complex procedures. We have attempted to provide for both needs.

When compared with other sources of emissions, smoke from forestry burning has been regarded by regulatory agencies as only locally important. Its components are thought of as natural, occur from other sources as well, and may even be deemed inevitable if we accept prescribed fire as merely a practical substitute for wildfire. The ecological necessity for fire in some forests and the use of controlled fire to avoid the devastation of wildfires are strong arguments for its prescription. Forest pathologists recognize fire as a needed sanitation measure in some situations. On the other hand, because some smoke components are toxic, because they may interact unfavorably with one another and with other chemicals in the atmosphere, and because they can also impair safe or esthetic visibility, alternatives to open burning are sometimes strongly advocated. Also, burning forest fuels, like all carbonaceous fuels, produce traces of such implicated carcinogens as benzo(a)pyrene. Because not all health-related threshold levels have been established, a first reaction could be to avoid all open burning.

In truth, knowledge of interrelating synergistic effects and of general human susceptibility to airborne toxins is still too imperfect to suggest elimination of all smoke as attainable, or even necessary. And while heavy debate continues over *safe* or *no-effect* proposals, a seemingly rational control approach may emerge. Rather than attempt to regulate emissions merely on the basis of our rapidly improving detection (i.e., analytical) capability, it is suggested that acceptable levels for naturally occurring, physiologically active pollutants be related to their ambient (or background) levels.

This is not to say alternatives to open burning are not preferred when possible. Neither is it intended as anything but a strong message to apply a meaningful principle:

AVOID OVERLOADING
NATURAL CLEARANCE
MECHANISMS—
BOTH PULMONARY AND ENVIRONMENTAL

By applying this principle, prolonged toxic contact and possibly increased physiologic effect on humans can be avoided. We believe that some smoke from forest management can be accepted in trade for benefits to the forest and for prevention of uncontrolled and overloading emissions from wildfire.

This Guidebook provides for the needs of both air and forest resource stewardship, and it is offered for local interpretation and use. It is offered, too, in the expectation that the health and well-being of the populace will be a primary concern of forestry smoke managers.

JOHN M. PIEROVICH
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CHAPTER I

SMOKE MANAGEMENT — WHAT IS IT?

by

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PURPOSE OF THESE GUIDELINES

This Guidebook is designed to help you determine in advance:

WHAT YOUR FIRE WILL PUT INTO THE AIR
WHERE THIS MATERIAL WILL GO
WHAT WILL HAPPEN TO IT
WHAT EFFECT IT WILL HAVE
WHAT YOU CAN DO ABOUT IT

. . .and doing something about it to minimize environmental impact is *smoke management.*

Fire in the forest—natural, accidental, or deliberate—has been an important process in the ecology of the South for thousands of years, especially in the fire subclimax pine stands of the Coastal Plains. The use of prescribed fire to accomplish specific forest management objectives is now regarded as an indispensable tool of the forest manager (Mobley and others 1973). Today, nearly 3 million acres a year are burned by prescription in the Southern United States. In the past, the forest manager had only a minimum of information to help him determine what smoke from a prescription fire would do to visibility or to the atmosphere.

This Guidebook was developed for southern forest-land managers who prescribe fires, and for public agencies that are responsible for maintaining air quality in southern rural areas where forests are burned. What is presented is based upon the best available technology. Because knowledge is presently incomplete, the scope is limited to:

A broad breakdown of important southern fuels

Single prescription fires

Predictions of particulate matter emissions only.

A SOURCE OF MORE INFORMATION

As this Guidebook is being written, a parallel *Forestry Smoke Management Sourcebook* is also being developed. This Guidebook provides a great deal of information to practitioners in condensed form, while the *Sourcebook* will provide much additional information to key specialists. Any references made to the *Sourcebook* are intended to let you know that additional information is already available—at least in manuscript form. The first edition of the *Sourcebook* will probably be distributed in 1977 to regional and areal levels of the Forest Service and to State Foresters in a looseleaf format.

WHAT'S IN THIS GUIDEBOOK

A lot of information is presented for the first time in this Guidebook. Much is based on limited data and will be subject to updating. New information includes:

A system for estimating total fuel loading

A system for estimating available fuel

Particulate matter emission factors for major fuel types and burning techniques

A procedure for determining particulate matter production rate

A procedure for predicting smoke concentrations at any target area.

All are described in Chapters IV and V. This information is put together in a step-by-step decision-logic framework in Chapter VI that can be used to predict what smoke from a planned burn will do to the immediate airshed, and how it will affect visibility at any point downwind.

Although much more information can be found in the *Sourcebook* that is being developed, Chapter II summarizes what is presently known about the components of smoke plumes and their effects. Chapter III briefly reviews the Clean Air Acts and resulting Federal standards, State regulations that pertain to forestry burning, and a proposed method for determining a voluntary limit on emissions.

THERE ARE ALTERNATIVES

When land managers want to reduce competing vegetation or debris, they have various treatment alternatives: open burning, mechanical treatment, chemical application, close utilization, and doing nothing. No one system or type of treatment will meet *all* needs. The common treatments and considerations affecting their choices are summarized in table 1.

Three special categories of alternatives need further discussion: fire, utilization, and no treatment.

FIRE

Burning may be for more than one purpose; but because reasons vary by treatment, the discussions that follow are categorized by specific treatment objectives. In each of the following sections, a brief discussion of the need to meet the objective is also provided.

Reduction of Hazardous Fuels

Flammable vegetation and litter accumulate rapidly in pine forests. This material is fuel for wildfires, and excessive accumulation must be controlled to minimize losses and damages. When fire is prescribed to reduce hazardous fuel accumulations, the stand is virtually fireproofed for the next year or two. Fuel begins to accumulate immediately, but wildfires that do occur are of lower intensity and much easier to control; they burn less area and cause less damage to the forest. In the South, prescribed fire is used primarily for this purpose.

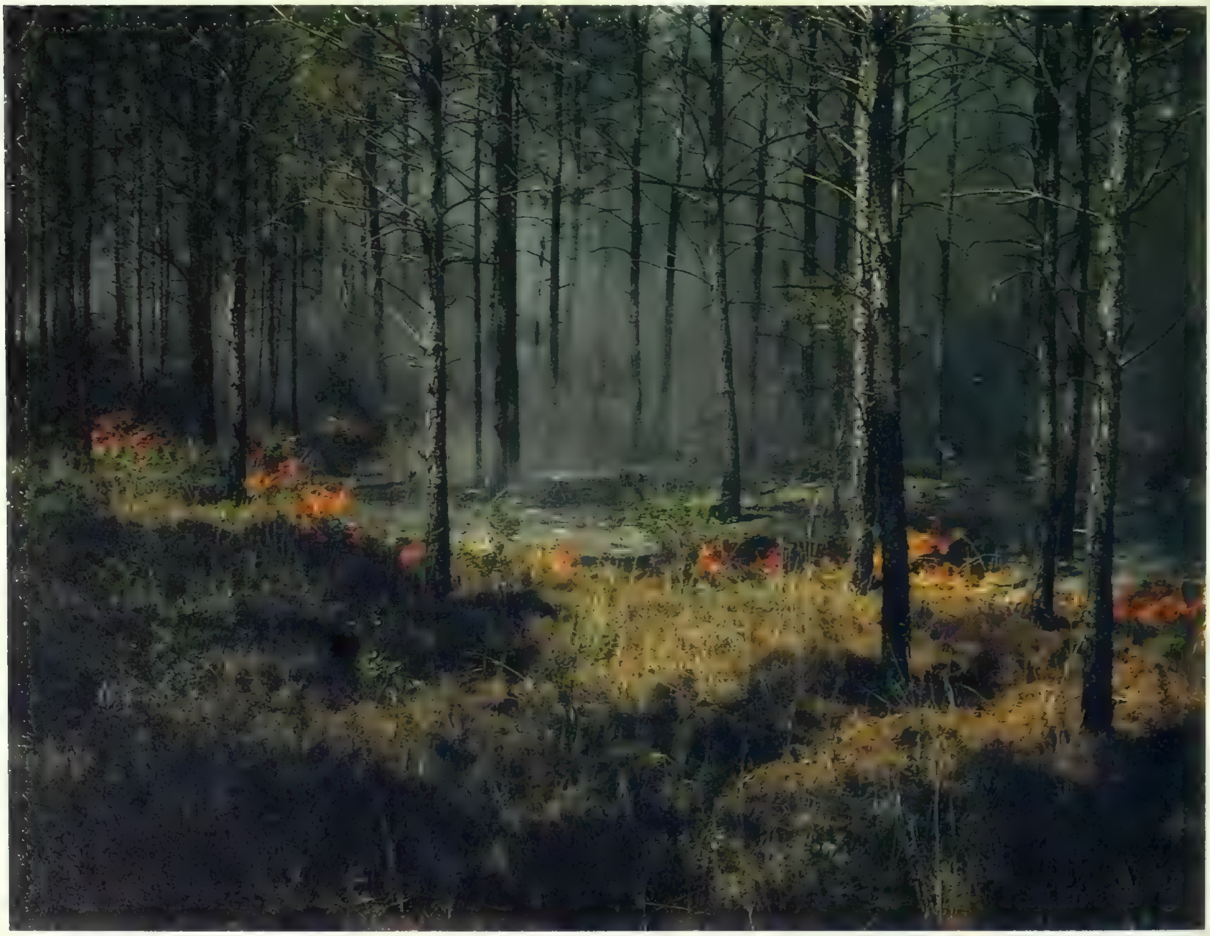

Figure 1. — Natural accumulations of understory vegetation are burned by prescription to reduce fire hazard.

Table 1.--Considerations in reducing forest debris by different treatments[1]

Considerations	Prescription burning	Chemicals	Forced-air burners
Adverse effect on air	Produces smoke	Chemical drift in foliar application	Very little visible emissions
Adverse effect on water	None[2]	May contaminate[3]	Negligible[2]
Adverse effect on soil	Negligible[2]	Negligible[2]	Some compaction[1]
Erosion	Possibly on steep slopes[5]	Negligible[2]	Possibly on steep slopes[4,5]
Overstory	Negligible[2]	Negligible[2]	Skin trees[4]
Energy use	None	None to very little	Very high
Portability at site	Yes	Yes	None
Transportation requirements	Crew truck	Crew truck &/or tank truck Spray unit if used	Lowboy & tractor (2 units)
Costs[6]	20¢ to $2.50/acre (avg. $1) Site preparation up to $6/acre	$20 to $45/acre (avg. $25)	$5 to $10/ton of material treated
Effectiveness under stands	Effective	Effective on all sizes (live vegetation only)	Not effective
Effectiveness in the open	Effective only on small material	Not effective on dead material	Effective
Advantages	Inexpensive Fast Multiple benefits	Versatile Can treat any size material	Can handle large boles
Disadvantages	Air pollution Usable days are limited Not effective on large material	Public disapproval Regulated Possible offsite effects Volume not reduced Increased fire hazard	Need support equipment Costly Cannot treat understory
Best use	Hazardous fuel reduction Wildlife habitat improvement Grazing improvement	Timber stand improvement or conversion	Change in land use Site preparation Right-of-way clearing

continued

Table 1.--Considerations in reducing forest debris by different treatments[1] (continued)

Considerations	Drum choppers	Rotary-blade choppers	Dozing or shearing and root raking	Total-tree chippers
Adverse effect on air	Only exhaust emissions	Only exhaust emissions	Only exhaust emissions	Only exhaust emissions
Adverse effect on water	Negligible[2]	Negligible[2]	Sedimentation if on slope	Negligible[2]
Adverse effect on soil	Possible compaction	Some compaction	Compaction and removal of topsoil	Some compaction
Erosion	Moderate to steep slopes[5]	Possibly on steep slopes[5]	Very susceptible[5]	Possibly on steep slopes[4, 6]
Overstory	Skin tree boles & damage roots	None	Excessive damage	Skin trees[4]
Energy use	High	High	High	Very high
Portability at site	Limited in stands	Limited in stands	Limited in stands	None
Transportation requirements	Lowboy & tractor	Lowboy & tractor	Lowboy & tractor	Lowboy & tractor (2 units)
Costs[6]	$30 to $50/acre	$10 to $20/acre	$50 to $125/acre	About $10/ton of material treated
Effectiveness under stands	Very limited Damage overstory	Limited	Cannot be used	Not effective
Effectiveness in the open	Effective	Effective on small material	Effective	Effective
Advantages	Effective in logging residue	Effective on small standing material Thorough treatment	Leaves ground clean	Salable product Can handle large boles
Disadvantages	Damages leave trees Blades tend to break on rocky ground	Limited where can be used	Debris left Erosion Costly Cannot treat understory	Need support equipment Initial investment Cannot treat understory
Best use	Site preparation	Maintenance of openings and rights-of-way	Change in land use Site preparation	Pulpwood logging Change in land use

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[1] Adapted from Harrison (1975).

[2] Improper use could cause some adverse effects.

[3] If long-term chemicals are used or if treatment is close to stream or reservoir.

[4] Support equipment.

[5] These treatments are not feasible on steep slopes due to erosion and/or excessive cost--and generally not needed.

[6] Costs are usually higher in Piedmont areas.

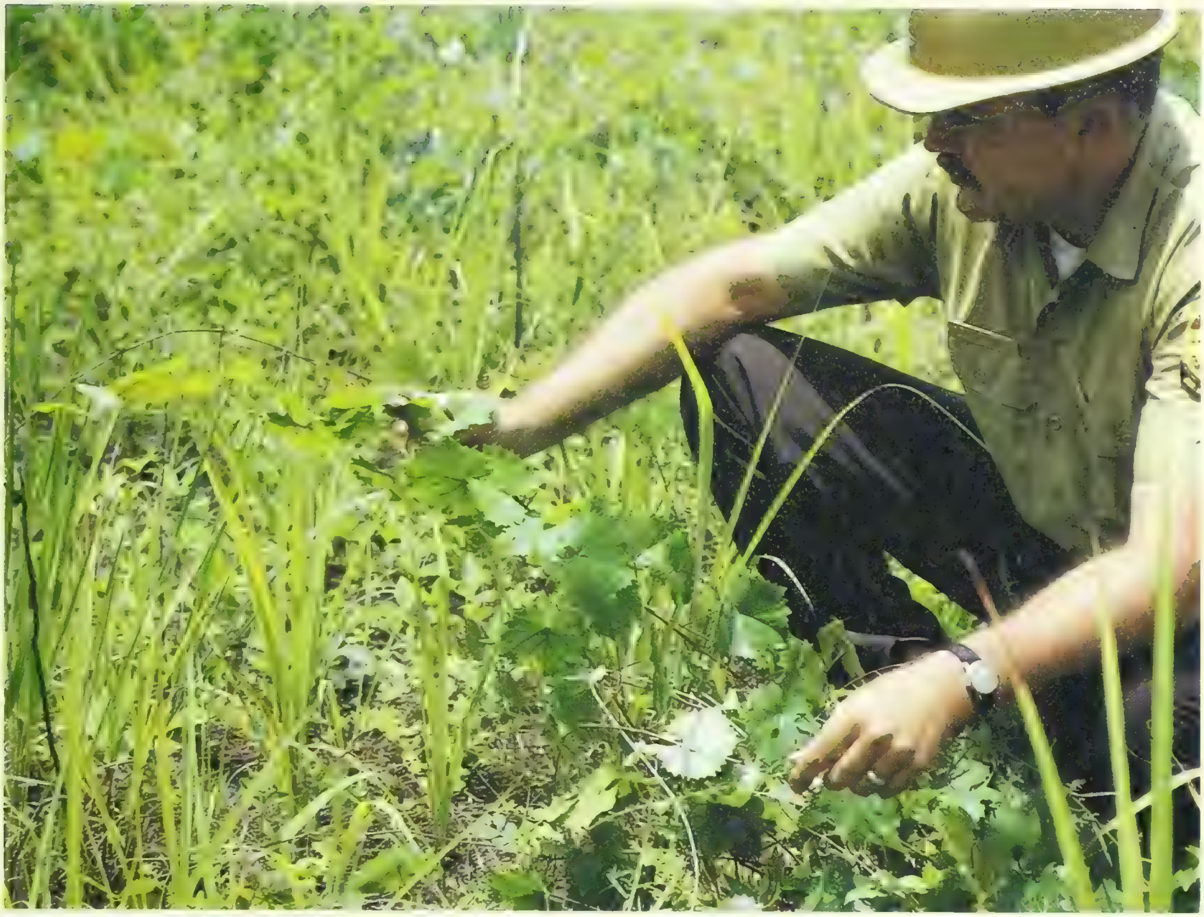

Figure 2. — Wildlife favor the newly sprouting vegetation that appears after a prescribed burn.

Wildlife Habitat Improvement

As shrubs mature, the amount of food available to wildlife declines. Fires are often prescribed by wildlife biologists to improve wildlife habitat. Unpalatable brush and litter are removed, allowing production of palatable new plants and sprouts. Seeds and insects are also more plentiful on burned areas.

Site Preparation

Litter and debris must be removed to reduce competition and prepare a proper site for tree seeding or planting. Mechanical treatments alone may create large, unmanageable accumulations of debris that occupy space needed for growing trees. This debris can tie up nitrogen needed by the new stand for a prolonged period. Furthermore, mechanical treatment alone often fails to expose the soil properly. On the other hand, burning alone is not very effective either—except when the volume of debris is very low. Where the volume of logging debris is large, fire is often used in conjunction with mechanical treatment.

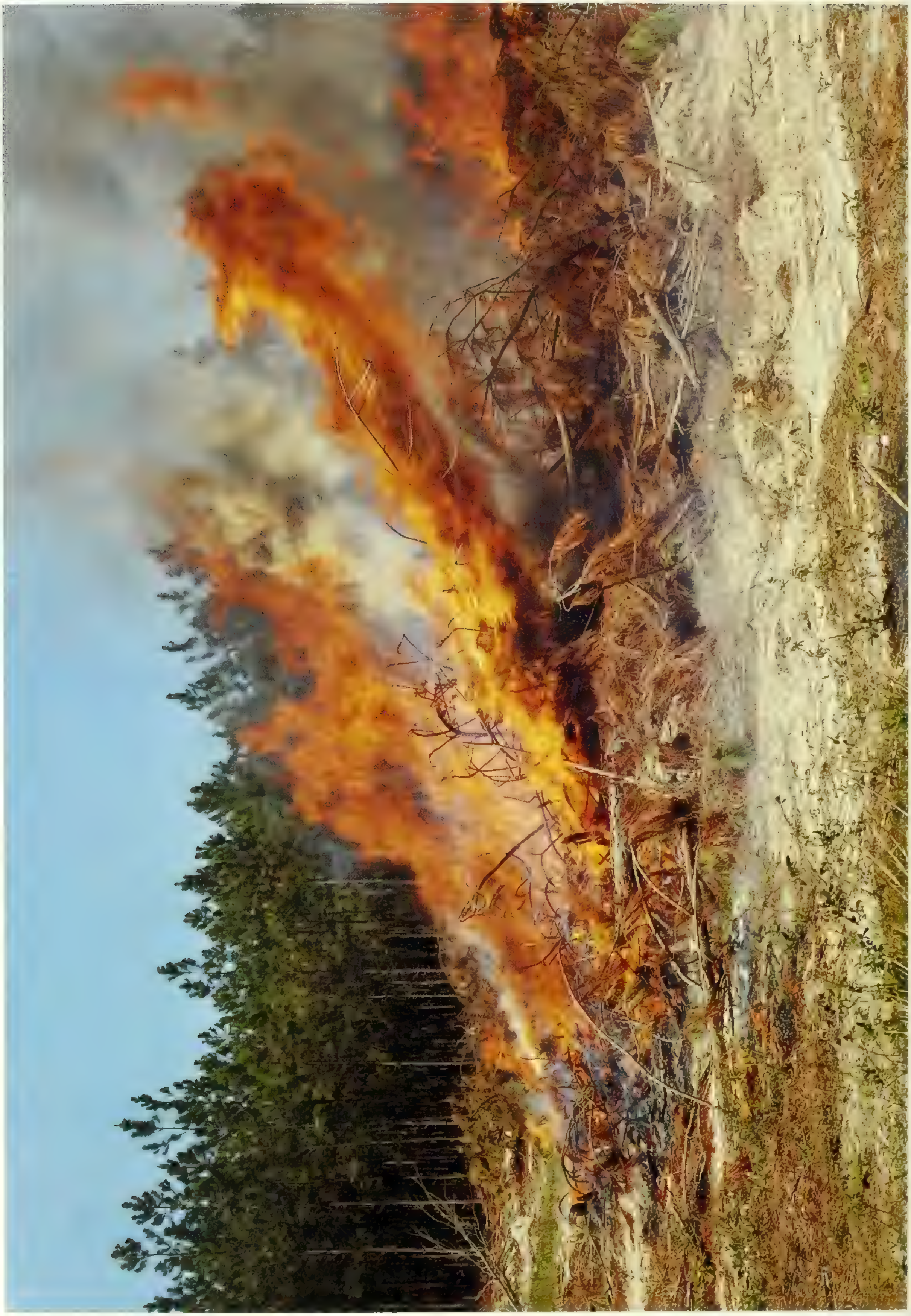

Figure 3. — Logging debris is burned by prescription to prepare sites for new crops of trees.

Control of Undesirable Species

In the absence of fire, most pine sites in the South tend to succeed to a climax type of scrub hardwoods. If these species are permitted to invade and compete with overstory pine, production is impaired and regeneration is very difficult.

Complete elimination of understory brush is not ecologically desirable or economically practical. It can be controlled with fire, however, if done while the understory is small. The resulting sprouts and growth of annuals provide good food and improved habitat for wildlife as well.

Disease Control

To control brownspot needle blight *(Scirrhia acicola* [Dearn.] Siggers) in longleaf pine *(Pinus palustris* Mill.) seedlings, the infected needles must be removed without damaging the bud. Fire is the only known practical way to properly remove the brownspot-infected needles of longleaf pines. Long experience with fire for this purpose has made it possible to do so without killing the bud.

Improve Forage for Grazing

Cattlemen produce beef on forested ranges. However, native grasses in the timber understory are smothered by shrubs and inferior hardwoods. Periodic, low-intensity fires control competition and maintain the grass species. In addition, the grass produced after such burning is especially nutritious and palatable for cattle.

Other Objectives

Other treatment objectives are to fireproof stands before initiating naval stores operations, to enhance esthetic appearance, and to improve accessibility for timber operators and hunters.

UTILIZATION

After allocating sufficient woody material to protect the soil from erosion, moisture loss, and unwanted loss of nutrients, most managers of commercial woodland would like to utilize all the remaining woody material for production of energy or as a raw material. Progress is being made in this

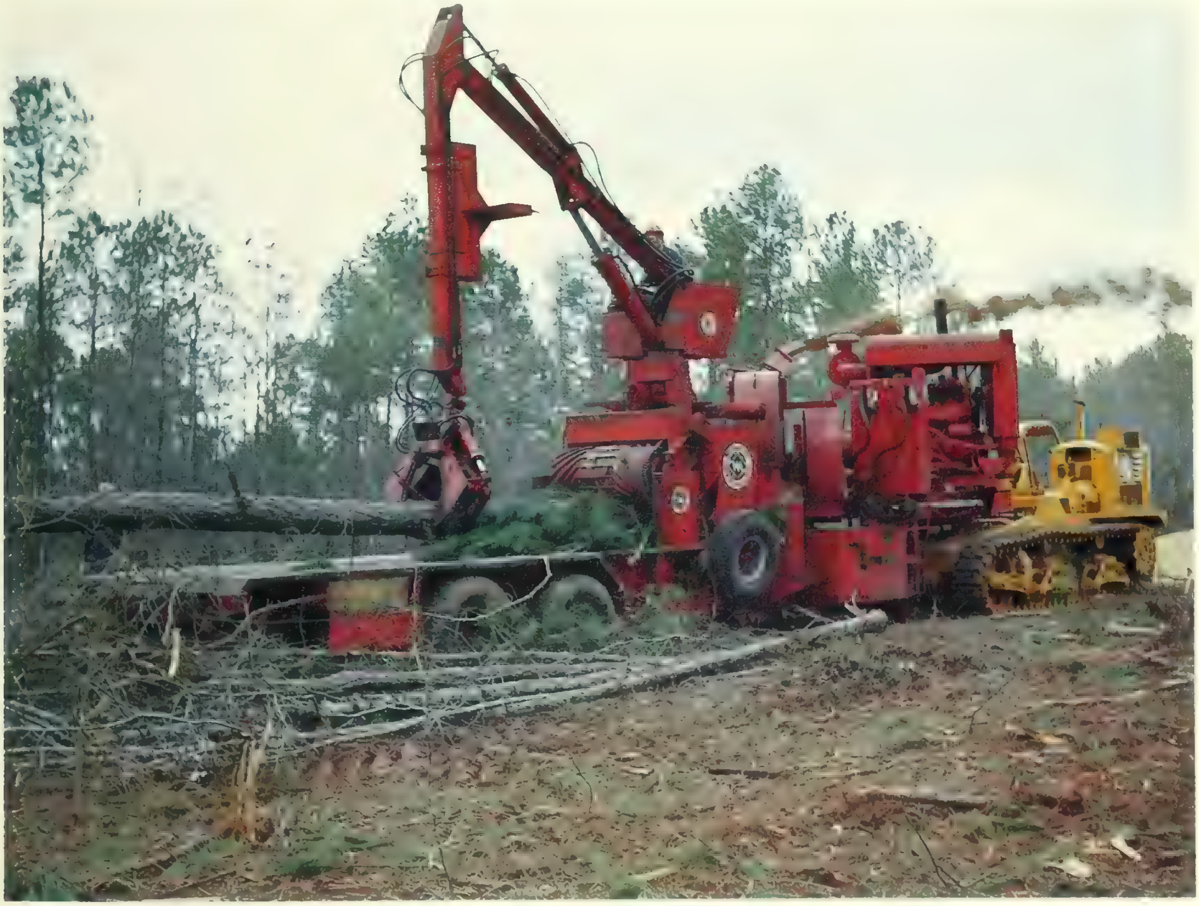

Figure 4. — Whole-tree chipping may be a practical alternative to burning in some places.

direction. In the South, merchantable pine trees are often utilized down to diameters of 2 to 4 inches. This is not usually the case, however, with hardwoods or forest areas being cleared for other uses.

One utilization system that looks promising is total-tree chipping. This system employs large, transportable chippers mounted on semitrailers. These will accept whole trees (limbs, leaves, and bark), cutting them into chips which can be blown into a truck and hauled to a pulpmill. No appreciable logging debris is left on areas logged in this manner. The investment cost and use of energy are high, but these disadvantages are offset where there is a market for such chips that contain bark and leaves. Some southern pulpmills can now accept substantial amounts of this type chipped material. Where such markets exist, total-tree chipping may be a better alternative than prescription burning. To meet energy needs, total-tree chippers can also be used to produce fuel for boilers. Studies and limited use are already underway.

Utilization of the small shrubs, brush, litter, and leaves within timber stands does not look promising. Volumes are too low and scattered to justify the cost of harvesting the material from among tree stems. Neither is there a developed market for most of this material. Pine needles can be sold for mulch when located close to metropolitan areas or nurseries.

NO TREATMENT

Choosing no treatment as an alternative—letting nature take its course—certainly has no immediate adverse effects on the quality of air, soil, or water. However, there can be other consequences:

Competition of unwanted plant species reduces timber growth.

Failure to prepare a site may make establishment of a new commercial timber stand difficult or impossible.

Wildlife habitat and food sources may disappear.

Palatable grass for cattle will be reduced or eliminated.

In stands of longleaf pine seedlings, mortality from brownspot disease will be increased.

Accessibility for hunting, timber management, and naval stores activites will be reduced.

Damage, as well as pollution of air and water, from wildfires will probably increase drastically—especially in areas of high fire occurence.

LITERATURE CITED

Mobley, Hugh E., Robert S. Jackson, William E. Balmer, and others

1973. A guide for prescribed fire in southern forests. Southeast. Area, State & Priv. For.-2, 40 p. USDA For. Serv., Southeast. Area, State & Priv. For., Atlanta, Ga.

Harrison, Robin T.

1975. Slash . . . equipment and methods for treatment and utilization. Equip. Dev. & Test Rep. 7120-7, 47p. USDA For. Serv. Equip. Dev. Center, San Dimas, Calif.

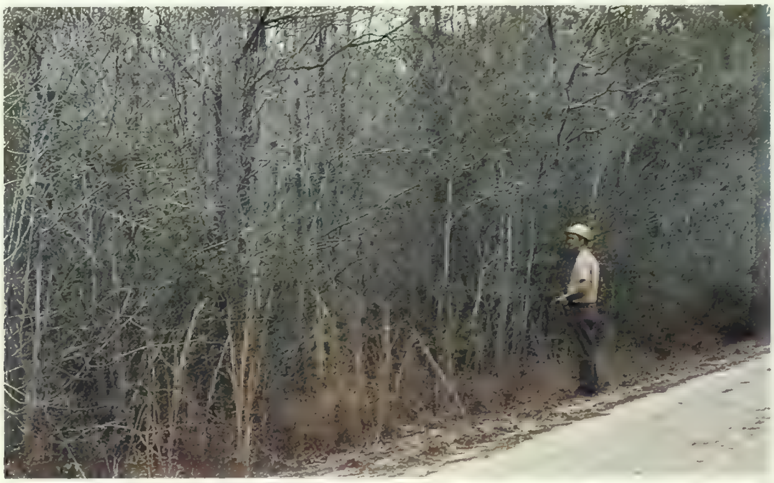

Figure 5. — Unless its growth is controlled in some manner, understory vegetation will take over desirable pine sites.

CHAPTER II

CONTENTS AND EFFECTS OF FOREST FIRE SMOKE

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The components of smoke are determined by the fuel and the process that converts this fuel to smoke. We therefore begin this Chapter with a description of the chemical elements of wood and the fuel. We then describe the process that first separates, and then recombines, these elements into the constituents of smoke. Although there are only a few major chemical elements in wood, the complex burning process results in numerous combinations and thereby generates a large number of chemical compounds.

We will then describe the products emitted from forest fires and their effects. Most investigators have measured only the major combustion products: carbon dioxide (CO_2), carbon monoxide (CO), total hydrocarbons (HC), and particulate matter. A few have measured nitrogen oxides (NO_x), organic acids, and aldehydes. The effects of forest fire smoke on man and his environment have not been measured directly. However, since the components of this smoke are similar to those of smoke from other combustion sources, we will draw information on effects from studies of individual components.

In the last section, we discuss particulate matter at some length. We provide detail on polycyclic organic matter (POM) and on physical characteristics. Size is perhaps the most important physical property of particulate matter. This size distribution is a good indicator of the potential for causing both health and visibility problems.

FUEL

The fuels of prescribed fires in the South, described in greater detail in Chapter IV, are mostly understory foliage, small branches, and the upper layers of ground litter. To a lesser extent, fuels also include the large branches and treetops left during land clearing and logging. Wildfires, which are often more intense than prescribed fires, may consume the foliage and small limbs of tree crowns, all litter layers, and organic soil. When burned, these fuel elements emit smoke with a chemical character that is basically determined by the chemical character of the fuel. Therefore, our discussion will start with an examination of the chemical character of forest vegetation.

CHEMICAL ELEMENTS OF WOOD

Chemical analysis of wood shows that it is composed of about 50 percent carbon, 6 percent hydrogen, 44 percent oxygen, and a fractional percent of what are called trace inorganic components. Surprisingly, there is only a minor difference in the major components between various wood species. The variability among trace components such as ash and nitrogen is greater. Ash content varies from 0.2 to over 0.9 percent for wood species in the United States. For nitrogen, the variation can be tenfold; for example, ponderosa pine *(Pinus ponderosa* Laws.) ranges from 0.13 percent nitrogen in boles to 1.04 percent nitrogen in growing needles.

More than half of the elements in the periodic table have been found in plants. At least 27 elements were identified in certain samples of white pine *(Pinus strobus* L.) wood and others doubtless occur in very small quantities.

Many of these elements are commonly recognized growth nutrients. Those occurring in fairly large quantities are called the major or macronutrients: nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Elements required in smaller quantities are the minor or micronutrients: iron, manganese, zinc, copper, boron, and molybdenum. This list may be expanded further as more is learned about plants. Table 2 shows an example of the type and concentration of trace elements.

Table 2. — Relative amounts of various elements found in dried leaf tissue of healthy plants[1/]

Element	Content	Content percentage
	Ppm	Percent
Nitrogen	20,000	2.0
Potassium	15,000	1.5
Calcium	15,000	1.5
Magnesium	3,000	0.3
Phosphorus	2,500	0.25
Sulfur	2,000	0.2
Iron	100	0.01
Boron	40	0.004
Manganese	40	0.004
Zinc	40	0.004
Copper	25	0.0025
Molybdenum	1	0.0001

1/ From Kramer and Kozlowski (1960).

Consideration of the trace components may seem trivial and unnecessary at first glance. Trace components, however, can cause major environmental problems. For example, the emission of sulfur oxides (regarded as a major pollutant) results from relatively minor amounts of sulfur in coal, oil, and other fossil fuels.

CHEMICAL COMPOUNDS IN WOOD

Ninety to ninety-five percent of the dry weight of wood is composed of three polymeric cell-wall constituents: cellulose, hemicellulose, and lignin. The other 5 to 10 percent includes constituents often listed as extractables or extraneous components. The extraneous components consist of several hundred individual chemical compounds that vary greatly between species, within species, and even within parts of the tree. In this group we find terpenes, tannins, resins, oils, pectins, gums, free organic acids, and minerals.

Wood contains between 41 and 53 percent cellulose. The composition of cellulose is quite uniform and independent of source; it consists of several hundred glucose-type carbohydrate units linked in a polymeric chain. Hemicellulose includes all noncellulosic polysaccharides such as the xylans, mannans, and glactans—plus related substances such as the uronic acids and their derivatives. No single, structural formula can be presented for this group; in fact, objections are often raised to the use of the collective term hemicellulose. The hemicellulose content of wood varies from 15 to 25 percent, depending on species. The lignin portion of wood is quite different chemically from cellulose and hemicellulose. It consists of polymeric, aromatic materials characterized by the presence of phenolic hydroxyl groups. Lignin includes a variety of substances that have similar chemical compositions, but may have structural differences. The basic building block of lignin is the phenyl propane unit. The lignin content varies from about 23 to 33 percent in softwoods, and from about 16 to 25 percent in hardwoods.

BURNING PROCESS

How the components of smoke are generated from burning forest vegetation is best understood by recognizing that fire is a two-stage process of pyrolysis and combustion. Although both stages occur simultaneously, pyrolysis occurs first; it is the initiating stage of chemical decomposition at elevated temperatures. It is most often viewed as a heat-absorbing (endothermic) reaction that converts large molecules into smaller ones. Fuel elements are separated into char, vapors, and high-molecular-weight hydrocarbons and particulate matter.

Combustion is the burning or rapid oxidation of the pyrolysate vapors escaping from the surface of the fuel. Defined in the most rigorous sense, combustion is a relatively fast, heat-releasing (exothermic), chemical reaction among pyrolysate vapors and oxygen.

Pyrosynthesis is a third activity that is a part of both the pyrolysis and combustion stages. It forms large and complex organic compounds from smaller free-radical hydrocarbons in the high-temperature and low-oxygen regions of the fuel and combustion zone. The formation of these compounds occurs in any combustion of carbonaceous fuel, and is due more to combustion characteristics than fuel characteristics.

Brown and Davis (1973), Browne (1963), and Murty Kanury (1972) have described what takes place during combustion of forest fuels. Combining their views, we can recognize three distinct phases of decomposition within fuel particles that are consumed. These phases—pre-ignition, flaming, and glowing—occur both sequentially and simultaneously in a moving fire front.

PRE-IGNITION PHASE (PYROLYSIS PREDOMINATING)

In this phase, the fuel is heated; volatile components move to the surface of the fuel and are expelled in the surrounding air. Initially, these volatiles contain large amounts of water vapor and some noncombustible organic compounds. As temperatures increase, hemicellulose, followed by cellulose and lignin, begin to decompose and release a stream of combustible organic products (pyrolysates). Because these gases and vapors are hot they rise, mix with the oxygen in the air, and ignite—producing the second phase.

FLAMING PHASE (GAS-PHASE OXIDATION PREDOMINATING)

In the second phase, the temperature rises rapidly from the heat of exothermic reactions. Pyrolysis continues, but it is now accompanied by rapid oxidation, or flaming, of the combustible gases being evolved in high concentrations. Carbon monoxide, methane, formaldehyde, organic acids, methanol, and other highly combustible hydrocarbon species are being fed into the flame zone. The products of the flame zone are predominantly carbon dioxide and water vapor. The water vapor here is not a result of dehydration as in the pre-ignition phase, but rather a major product of the oxidation of the fuel constituents.

Some of the pyrolyzed substances cool and condense without passing through the flame zone; others pass through the flames but only partially oxidize, producing a wide range of products. Many products of low molecular weight (methane, propane, etc.) remain as gases after cooling. Others, with higher molecular weights, cool and condense to form small, tarry, liquid droplets and solid soot particles as they move from the combustion zone. These condensing substances, along with the rapidly cooling water vapor that is being evolved in copious amounts, form the smoke that accompanies all forest fires.

Pyrosynthesis also occurs during this phase. Low-molecular-weight hydrocarbon radicals condense in the reducing region of the flames, leading to the synthesis of relatively large molecules such as the polynuclear aromatic hydrocarbons.

GLOWING PHASE (SOLID OXIDATION PREDOMINATING)

In the final phase of combustion, the exposed surface of the char left from the flaming phase is oxidized, producing a characteristic glow. This continues, as long as temperatures remain high enough, until only small amounts of noncombustible minerals remain as gray ash. Many times the arrangement of the burning material is such that temperatures cannot be maintained, and black char is left instead of gray ash.

Fuel particles are not always consumed in a moving fire front. Because of the size, condition, or arrangement of these particles, some are pyrolyzed but not oxidized and others are only partially consumed before the flame is extinguished. From the heat still available after the flaming phase, these particles emit large amounts of smoke. Still other particles continue in flaming combustion after the flaming phase has ended. As a result dehydration, pyrolysis, solid oxidation, and scattered flaming often occur simultaneously during this last phase. Where this condition exists, this last phase is called smoldering.

In subsequent Chapters, two fire phases are described: one with convective lift and one without. These phases are related to the activity of the convection column and not to the pre-ignition, flaming, glowing, and smoldering phases just described. In the convective-lift phase most emissions are entrained into a definite convection column. In the no-convective-lift phase, most emissions are not entrained into a definite convection column. The smoldering phase described in this Chapter occurs in both the convective-lift and no-convective-lift phases.

The discussion that follows covers the gases, vapors, and suspended particulate matter found in forestry smoke. Because of the special importance of particulate matter, a separate section will follow the more general discussions of primary and secondary emissions.

PRIMARY PRODUCTS

The burning of forest fuels emits hundreds, if not thousands, of chemical compounds into the atmosphere. An appreciation of the complexity of smoke can be obtained by a quick glance at research on the chemical characterization of tobacco smoke. As of 1968, over 10,000 publications had reported the identification of over 1,200 chemical compounds. To date, over 200 compounds have been identified in woods smoke.

Amounts of carbon dioxide and water vapor emitted are indicators of burning efficiency. The more efficient the combustion, the more CO_2 and water vapor produced. As combustion efficiency decreases, the proportion of undesirable emissions increases. Efficiency varies with the fuel moisture, fuel loading, type of fire (heading versus backing), and to a lesser extent, weather conditions. Perhaps the most dramatic finding to date is that heading fires produce approximately three times more particulate matter than backing fires. Wet fuels produce substantially more particulate matter than dry fuels.

Scientists have shown that amounts of emissions per ton of fuel consumed (emission factors) vary widely (table 3). In most cases, investigators measured only CO_2, CO, total hydrocarbons (HC), and particulate matter. In a very few instances they measured nitrogen oxides, aldehydes, and organic acids. Data on the latter groups are insufficient to estimate their emission factors with reasonable accuracy. Most studies have been limited to those emissions that are currently covered by the National Ambient Air Quality Standards.

Table 3. — Range of emission factors for components of forest fire smoke, with effect potentials

Components	Range of emission factors (pounds produced per ton of fuel consumed)	Effect potentials
Carbon dioxide	[1] 2,000-3,500	No direct
Water vapor	500-1,500	Visibility
Carbon monoxide	20-500	Health
Total suspended particulate matter	20-180	Visibility & health
Total hydrocarbons	10-40	Visibility & health [2]
Other organics	Unknown	Visibility & health [2]
Nitrogen oxides	1-9	Visibility & health [2]
Sulfur oxides	Negligible [3]	Health

[1] Values higher than 1 ton occur because of the chemical combination of carbonaceous constituents with oxygen in air to produce carbon dioxide.

[2] Includes effects from secondary photochemical products.

[3] A possible exception in the high-sulfur peat or "muck" soils.

In forest fires, the two products of complete oxidation—carbon dioxide (CO_2) and water vapor—make up over 90 percent of the mass emitted. The other 10 percent includes virtually all of the smoke and potential problem compounds. Products of major concern are carbon monoxide, particulate matter, gaseous hydrocarbons, other organic compounds, and the nitrogen oxides.

The effects of smoke from forest fires on man and his environment cannot yet be directly measured. We can only consider the potential effects of components known to exist in this smoke. The components that are potentially most harmful to humans are the volatile organic compounds and the particles. Both temporary and lasting effects must be considered. The potential for a lasting effect is reduced by the detoxification capability of the body organs. Even compounds that can act synergistically to cause cell damage at levels below the threshold effect of each compound alone are a threat only in dosages above the body's capacity for detoxification.

CARBON DIOXIDE (CO_2)

Carbon dioxide is an odorless and colorless nontoxic gas formed abundantly in nature by the decomposition of organic substances. It is exhaled by man and animals during breathing and absorbed from the air by plants for use in photosynthesis. Its only potential as a pollutant is as a contributor to the overall greenhouse effect that may be causing a rise in the Earth's air temperatures.

WATER VAPOR (H_2O)

Water vapor is important because it can affect visibility near a fire, and because it interacts with the other combustion products to reduce combustion efficiency. It is theoretically possible to produce 1,720 pounds of water from a ton of fuel at a moisture content of 30 percent. Six hundred pounds are unbound, or free water, and 1,120 pounds are from the combustion reaction.

CARBON MONOXIDE (CO)

Carbon monoxide is a colorless and odorless toxic gas. Although concentrations of this gas can be quite high (100 to 200 ppm) right at the fireline, measurements on low-intensity prescribed fires show that normal atmospheric dilution processes are quite rapid—reducing this level to below 10 ppm approximately 100 feet downwind. Although the subject has been studied in depth and is still debated, reviews of the literature by Hueter and others (1972), Bartlett (1973), and Horvath (1973) indicate that the concentrations would probably have to exceed 10 ppm for a lengthy period to produce serious effects.

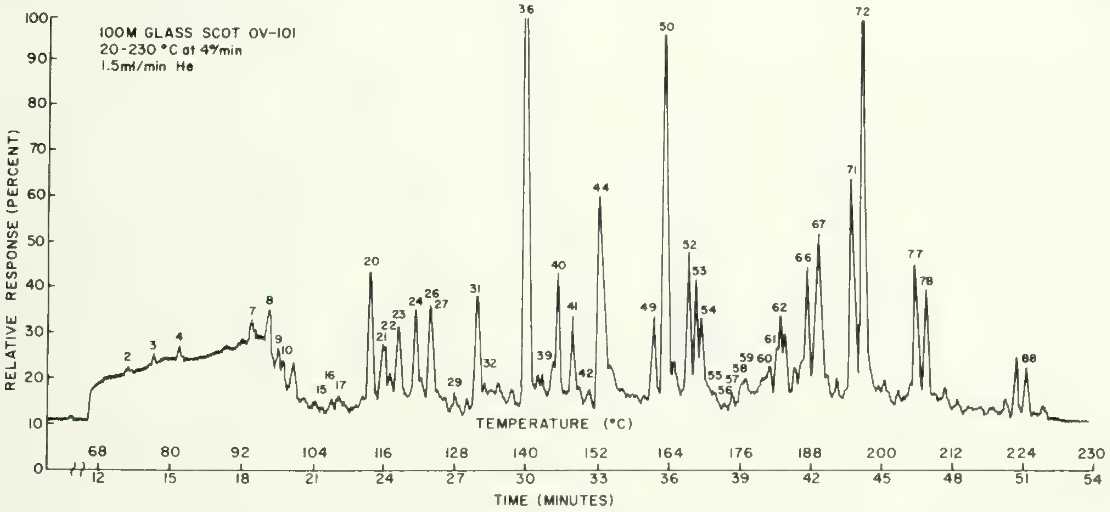
HYDROCARBONS (HC)

Hydrocarbons are organic compounds containing only carbon and hydrogen in the molecule. Two groups of hydrocarbons are particularly important potential pollutants: the low-molecular-weight olefins or unsaturated hydrocarbons and the high-molecular-weight, aromatic-type hydrocarbons. Methane, ethylene, and acetylene are the predominant low-molecular-weight hydrocarbons in forest fire smoke, comprising as much as 50 percent of the total. Lesser amounts of ethane, propane, propylene, methyl and ethyl acetylene, and butene and butane isomers have also been found. Characterization of the high-molecular-weight hydrocarbons to date is too fragmented and incomplete to draw any meaningful conclusions.

Hueter and others (1974) report that the hydrocarbons propylene, acetylene, and ethylene are known to affect plants. However, the amount of propylene in smoke is too small to be of direct concern, and both propylene and acetylene are considerably less phytotoxic than ethylene. Also, exposure from forest fire smoke is believed likely to be of too short a duration for any appreciable direct adverse effect from ethylene.

OTHER ORGANIC COMPOUNDS

In addition to the hydrocarbon organic compounds, there are literally hundreds of other organic gases and vapors in forest fire smoke. Figure 6 is a chromatogram of organic vapors



PEAK	COMPOUND
2	isopentane
2B	l-pentene
2C	furan
3	*n*-pentane
3A	isoprene
3B	acetone
4A	isopropanol
4B	cyclopentadiene
7	diacetyl
8	l-hexene
8A	methyl vinyl ketone
9	2-methylfuran
10	*n*-hexane
15	2,4-hexadiene
16	l,3,5-hexatriene
17	3-methylbutanal
20	benzene
21	cyclohexane
22	4-methylpentene
23	2,4-dimethylpentane
24	l-trans-2-dimethyl-cyclopentane

PEAK	COMPOUND
24A	sorbaldehyde (tent.)
26	2,5-dimethylfuran
26A	*n*-heptane
27	*cis*-2-heptane
29	2-vinylfuran
31	2,3-dimethyl-2-pentane
32	2,4-dimethylhexane
36	toluene
39	l-octene
40	2,3-dimethylhexa-l,4-diene
41	*n*-octane
42	2,3,5-trimethylfuran
44	furfural
49	ethyl benzene
50	*p*-xylene
50A	2-propionylfuran (tent.)
52	styrene
53	*o*-xylene

PEAK	COMPOUND
54	*n*-nonane
54A	2-isopropylfuran
55	anisole
56	2-methyl-5-isopropenylfuran
57	cumene
58	*n*-decane
59	camphene (tent.)
60	*n*-propylbenzene
61	*m*-ethyltoluene
62	*p*-ethyltoluene
66	l-decene
67	benzofuran
71	*m*-diethylbenzene
72	limonene
77	*p*-α-dimethylstyrene
78	*n*-undecane
88	*n*-dodecane

Figure 6. — Chromatogram of organic vapors in loblolly pine smoke. Each peak represents a separate compound.

sampled from a laboratory fire of loblolly pine *(Pinus taeda* L.) needles. Each peak represents a separate compound. This display includes only some of the organic compounds in smoke—principally those with 4 to 12 carbon atoms. Included in this fraction are many oxygenated compounds—mostly organic acids, aldehydes, and furans—plus many high-molecular-weight aliphatic and aromatic hydrocarbons. Several low-molecular-weight and oxygenated species, especially the carboxylic acids (formic and acetic acids, etc.) and the reactive aldehydes (formaldehyde, acetaldehyde, acrolein, etc.) have been reported as minor, but significant, constituents of woods smoke.

In extensive reviews of the health effects of volatile organic compounds, Balchum (1973) and Hueter and others (1974) point to the lower molecular-weight and more soluble aldehydes—such as formaldehyde—as irritants to the mucous membranes of the eyes and upper respiratory tract. Formaldehyde irritates the eyes, nose, and throat at levels of 0.01 to 1.0 ppm, causes discomfort at 2.0 to 3.0 ppm, and can only be tolerated for 10 to 30 minutes at 4.0 to 5.0 ppm. The higher molecular-weight and less soluble aldehydes are deep-lung irritants.

Balchum (1973) and Hueter and others (1974) have found that the unsaturated aldehydes are several times more irritating and toxic than the saturated aliphatic aldehydes. Within the saturated and unsaturated aldehydes, toxicity increases with decreasing molecular weight. For example, unsaturated acrolein can cause moderate irritation of the eyes and nose within 5 minutes at levels as low as 0.25 ppm and becomes intolerable at 5.0 ppm within this same time. In contrast, saturated acetaldehyde does not become an irritant until it reaches a concentration of 50 ppm, far above anticipated levels.

OXIDES OF NITROGEN (NO_x)

Oxides of nitrogen (NO_x) include both nitric oxide (NO) and nitrogen oxide (NO_2). NO is a colorless gas that, in contact with air, forms NO_2, a reddish-brown gas. The normal mechanism for the formation of oxides of nitrogen in combustion is through fixation of atmospheric nitrogen and oxygen in the burning zone, principally at temperatures above 1,600° C. This is above temperatures normally occurring in prescribed forest fires. However, these temperatures could be achieved in piled slash or wildfires.

Nitric oxide can also be formed at lower temperatures in the presence of hydrocarbon-free radicals (Ay and Sichel 1976). Significant amounts of nitric oxide may be formed in this way in forest fires. Nitrogenous compounds in forest fuels are another potential source of oxides of nitrogen in emissions. Information on nitrogen oxide emission rates from forest fires is scanty and inconclusive.

NO_2 is about four times more toxic than NO and exerts its primary effect on the lungs. However, based on the reviews of Hueter and others (1973) and Shy (1973), concentrations far exceeding those expected of a forest fire are required for direct effects on man. The real importance is in the formation of a whole train of secondary products.

SULFUR OXIDES (SO_x)

Sulfur oxides are probably produced only in negligible quantities because most forest fuels contain less than 0.2 percent sulfur. Sulfur oxides have not yet been detected in forest fire smoke. A notable exception is certain organic soils in Florida which have a sulfur content of about 4 percent and are under current investigation.

SECONDARY PRODUCTS

We have briefly reviewed the major findings on primary or fire-produced emissions and their effects. As smoke plumes travel through the atmosphere, secondary products can be generated through mixing of primary effluents or photochemical activity. Evans and others (1974), for example, reported formation of ozone in the upper layer of a smoke plume when it was irradiated with sunlight. Some secondary products are more harmful than the primary products, and some are harmless.

Health effects due to the interaction of particulate matter and sulfur dioxide have been found in numerous air pollution studies (Engel and others 1971, National Academy of Sciences 1973 and 1975). Our current studies, while only yielding tentative results, tend to confirm that these and other secondary reactions will take place.

PARTICULATE MATTER

In this Guidebook, particulate matter is defined as any dispersed aggregate matter, solid or liquid (other than water), that for practical purposes is larger than about 0.002 micron in diameter, but smaller than 500 microns in diameter. The size, shape, porosity, density, and other physical properties of particulate matter are highly variable. Aerosol, another often-used term, is considered here to mean small, airborne particulate matter.

Particulate matter remains suspended in the atmosphere for periods of a few seconds to several months. Suspended particulate matter is that portion which, because of its small size (below 5 to 10 microns in diameter), is transported long distances in the atmosphere and has the greatest potential for environmental impact. Suspended particles are of greatest concern in smoke management.

The most obvious environmental effect of smoke from prescribed forest fires is a reduction in visibility. This effect is caused by the particles that absorb and scatter light, washing out the contrast that exists between the source and its background. These particles can also scatter the sunlight that illuminates the air between the source and the receiver, again washing out the contrast as distance increases. This temporary reduction in visibility can hinder safe operation of aircraft and automobiles or the enjoyment of scenic vistas.

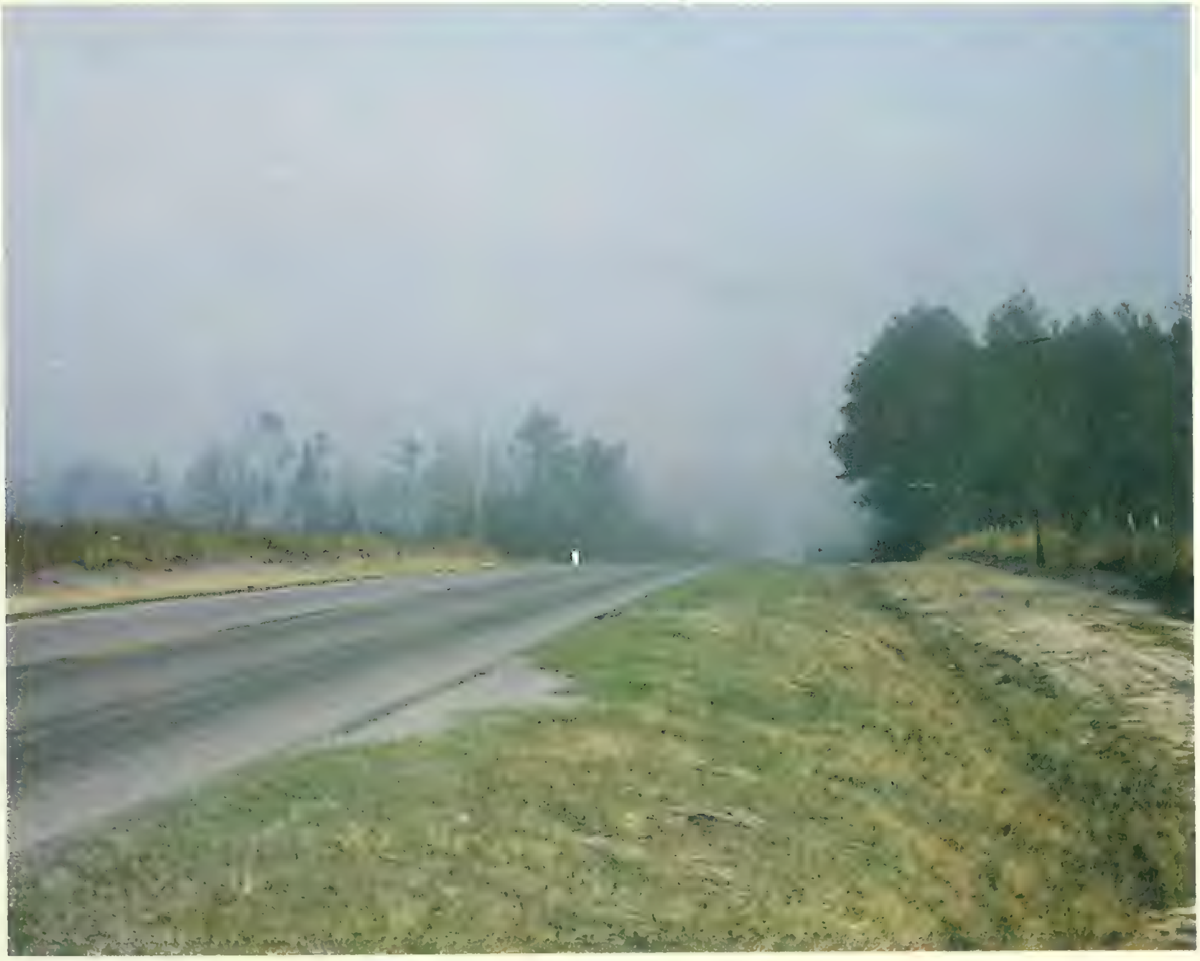


Figure 7. — A reduction in visibility is the most obvious adverse effect of smoke on the environment.

The soiling ability of larger carbon-type particles is another environmental effect of forest fires; but in prescription burning, these particles tend to fall out of the smoke column close to the fire rather than adding to the general pollution level.

A term that is increasing in popularity and significance is fine particulate matter (or sometimes, respirable suspended particulate [RSP]) which comprises particles below 2 to 3 microns. These have an especially long residence time in the atmosphere, contribute to smog formation, and penetrate deeply into the lungs. Also, they may act synergistically with gases or other particles.

According to the review of Engel and others (1971), particulate matter may contribute to accelerated corrosion of metals upon which they are deposited by sorbing corrosive chemicals from the atmosphere. Almost all of this information comes from studies of urban versus rural areas where gaseous pollutants in the urban areas are adding to the corrosion.

Health effects of particulate matter are determined by three properties: size, sorption, and chemical composition. Sizes of particles are important because of their relation to different parts of the respiratory system. The three main parts of the respiratory system are the nasopharyngeal, tracheobronchial, and pulmonary. Of these, the upper two contain cellular tissue with hairlike outgrowths (cilia) covered with mucus, and the lower one contains moist cellular tissue covered by a surface-active material to prevent the collapse of the air sacs at the end of respiration. Through inertial impaction and gravitational settling, the larger particles are deposited in the upper two parts of the system and then expelled. As the size decreases below 5.0 microns in diameter, increasing numbers are deposited in the lower respiratory tract—including over 50 percent of those between 0.01 and 0.1 micron that penetrate this far. Many forest fire smoke particles, as shown in the physical properties subsection, have a potential for being deposited deep in the lungs.

Sorptive properties of particles make them potential carriers of toxic material. In a review of the effects of particles on health, Engel and others (1971) found that formaldehyde, which does not itself readily penetrate the upper respiratory tract, is carried to the lungs by adsorption to small particles—causing increased toxic effect. In their review of hydrocarbons, Hueter and others (1974) found that the toxicity of acrolein and formaldehyde (both constituents of forestry smoke), when in the presence of certain inert aerosols, appeared more toxic to mice.

Particulate matter can consist of just a few easily analyzed solid inorganic compounds as in some industrial smoke, or it can consist of several hundred liquid and solid compounds in a complex organic/inorganic matrix as in certain natural aerosols. Examples of natural particulate matter are: (1) the coarse, inorganic mineral dust particles derived from windblown soil, (2) the inorganic sea-salt particles emitted from the oceans, (3) the powderlike, organic pollens from plants, and (4) the organic aerosols produced by forest fires.

Solvent extractions with benzene have traditionally been used to estimate the amount of organic compounds in particulate matter. The benzene soluble organic (BSO) fraction of particulate matter from fires in various southern fuels has been found to range from 40 to 75 percent. Some of this variation is due to the type of fire. In comparison, the average BSO fraction of ambient air particulate matter is about 8 percent.

The BSO percentage, while a measure of the organic content of particles, gives no information about the individual organic compounds. Very little of the chemical analysis required for this has been accomplished for forest fire particles. However, a considerable amount of analysis of the smoke in flavoring food, from tobacco, and from burning building materials has been completed. Those analyses that covered the burning of cellulose, hemicellulose, and lignin have identified several hundred organic compounds in the particulate matter. These compounds, expected to be a part of forest fire smoke, are categorized in the general classes: organic acids, alcohols, aldehydes, furans, ketones, and aromatic compounds. The aromatic compounds include the esters, phenols, and polycyclic organic matter.

POLYCYCLIC ORGANIC MATTER

Polycyclic organic matter (POM) is of special interest in smoke management because it is a class of compounds containing many physiologically active substances. Benzo(a)pyrene (BaP) and other implicated carcinogens are usually found in POM.

POM is formed by the pyrosynthesis of small carbon fragments into large hydrocarbon molecules in the low-oxygen region of combustion processes. It is found in virtually all burning which involves carbonaceous fuels. Production of POM is more dependent on the conditions of the fire than the type of carbonaceous fuel. For example, inefficient, residential coal furnaces produce substantially more benzo(a)pyrene per unit of fuel consumed than do more efficient coal furnaces in power plants (National Academy of Sciences 1972).

In recent laboratory experiments, BaP concentrations were measured in the smoke from burning slash pine *(Pinus elliottii* Engelm.) needles. With the laboratory burning tray on a slope of 50 percent, heading and backing fires (two replicates) were set at three loadings (pounds per square foot) each.

Heading fires, as expected, usually produced more particulate matter per ton of fuel at a given fuel loading (table 4). Backing fires, however, produced substantially more benzo(a)pyrene, especially at light loadings.

Within heading fires, the smoldering phase produces higher amounts of both BaP and particulate matter than the corresponding flaming phase (table 5).

The differences in BaP production can be explained partly by the conditions required for its formation—moderately high temperatures, low oxygen, and long residence times in the reaction zone. Carbon fragments in the slow-moving, backing fires (especially the light loadings) remained under these optimum formation conditions substantially longer than in the heading fires. Within heading fires the carbon fragments in the

Table 4. — Benzo(a) pyrene (BaP) and total suspended particulate matter (TSP) from burning pine needles 1/

Type of fire and fuel loading (pounds per square foot)	Emissions	
	Benzo(a)pyrene	Total suspended particulate matter
	ng/g 2/	Pounds per ton 3/
Backing:		
Light (0.1)	3,500	22
Medium (0.3)	560	8
Heavy (0.5)	240	5
Heading:		
Light (0.1)	38	22
Medium (0.3)	40	88
Heavy (0.5)	100	129

1/ Fuel moisture content for all fires ranged from 18 to 27 percent.

2/ Nanograms of benzo(a)pyrene per gram of fuel burned. A nanogram is 0.000000001 gram.

3/ Pounds of total suspended particulate matter per ton of fuel burned.

smoldering phase, even though at less than optimum BaP formation temperatures, are subject to these conditions for substantially longer periods than in the corresponding flaming phase.

The benzo(a)pyrene levels shown in tables 4 and 5 are generally in the ranges reported elsewhere for open burning of landscape refuse, grass clippings, leaves and branches (National Academy of Sciences 1972), and hardwood leaves (Jones 1975). The one exception is the value we observed for lightly loaded backing fires. That value is about 10 times what we might have expected from reading earlier study results.

Table 5. — **Benzo(a)pyrene (BaP) and total suspended particulate matter (TSP) from flaming and smoldering phases of burning pine needles** [1]

Fire phase and fuel loading (pounds per square foot)	Emissions	
	Benzo(a)pyrene	Total suspended particulate matter
	ng/g [2]	Pounds per ton [3]
Flaming:		
Light (0.1)	33	14
Medium (0.3)	17	17
Heavy (0.5)	36	40
Smoldering:		
Light (0.1)	100	59
Medium (0.3)	55	143
Heavy (0.5)	140	192

[1] Fuel moisture content for all fires ranged from 18 to 27 percent.

[2] Nanograms of benzo(a)pyrene per gram of fuel burned. A nanogram is 0.000000001 gram.

[3] Pounds of total suspended particulate matter per ton of fuel burned.

General conclusions about benzo(a)pyrene in forestry smoke cannot be drawn at this time. The levels we found in our limited number of laboratory fires were very low to moderate. Our data may indicate, however, that one should be cautious in declaring backing fires to be the cleanest. It is true that backing fires can be expected to produce a lower volume of all particulate matter than heading fires. But, it appears that some backing fires can be expected to produce more BaP than heading fires.

PHYSICAL PROPERTIES

The particulate fraction of forest fire smoke is highly variable. As we have shown, this high variability is not only in the mass produced but also in the size, shape, porosity, density, and other physical properties of individual particles. Particles are responsible for two major smoke problems: respiratory effects and visibility reduction. Respiratory effects have been discussed previously.

Visibility reduction is caused by the scattering of light by the particles. All particles do not scatter light to the same degree. Those having diameters within the wavelength of visible light, between 0.3 and 0.8 micron, cause the maximum scattering. Unfortunately, these sizes of particles remain suspended in the air the longest.

Particle Formation

The majority of particles in forest fire smoke are formed from the gaseous organic compounds produced by pyrolysis and combustion. Nucleation, condensation, and coagulation form both liquid and solid particles ranging upward in size from about 0.002 micron. From 60 to 70 percent of the total particles produced are liquid. These are formed into a spherical shape by the condensation of organic vapors and range from the highly volatile and short lived to the long lived, tarry, and viscous. Figure 8 is a photomicrograph that shows both the spherical liquid particles and the irregular solid particles.

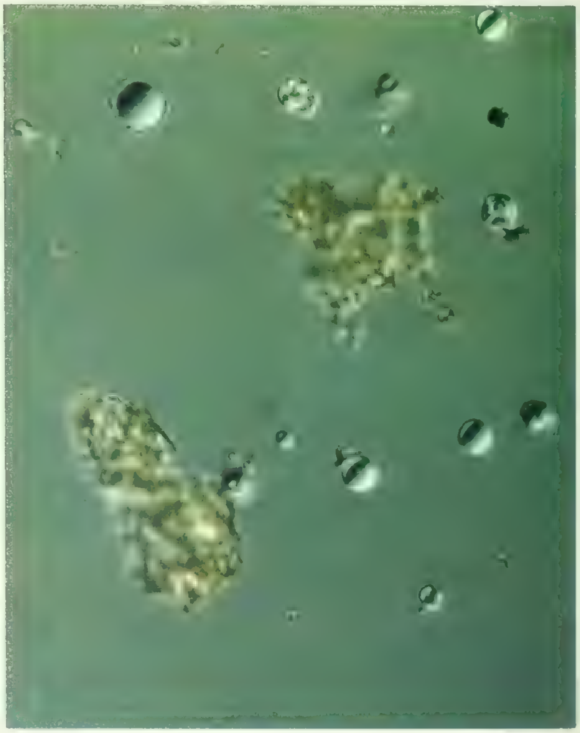


Figure 8. — Liquid particles are spherical, whereas solid particles are irregularly shaped. Characterizing particle shapes often helps in evaluating environmental effects.

Solid particles created by the combustion process, particularly the smaller ones, can also assume a spherical shape. More commonly, however, they assume other forms that approximate flattened discs, angular cubes, and long, chainlike agglomerates. Sizes of the solid particles range from 0.01 micron to 5 microns in diameter. Frequently, the small particles will bind together to produce larger agglomerates that vary in shape from roughly circular to long, slender, chainlike masses. Figure 9 is a scanning electron micrograph illustrating these agglomerated particles.

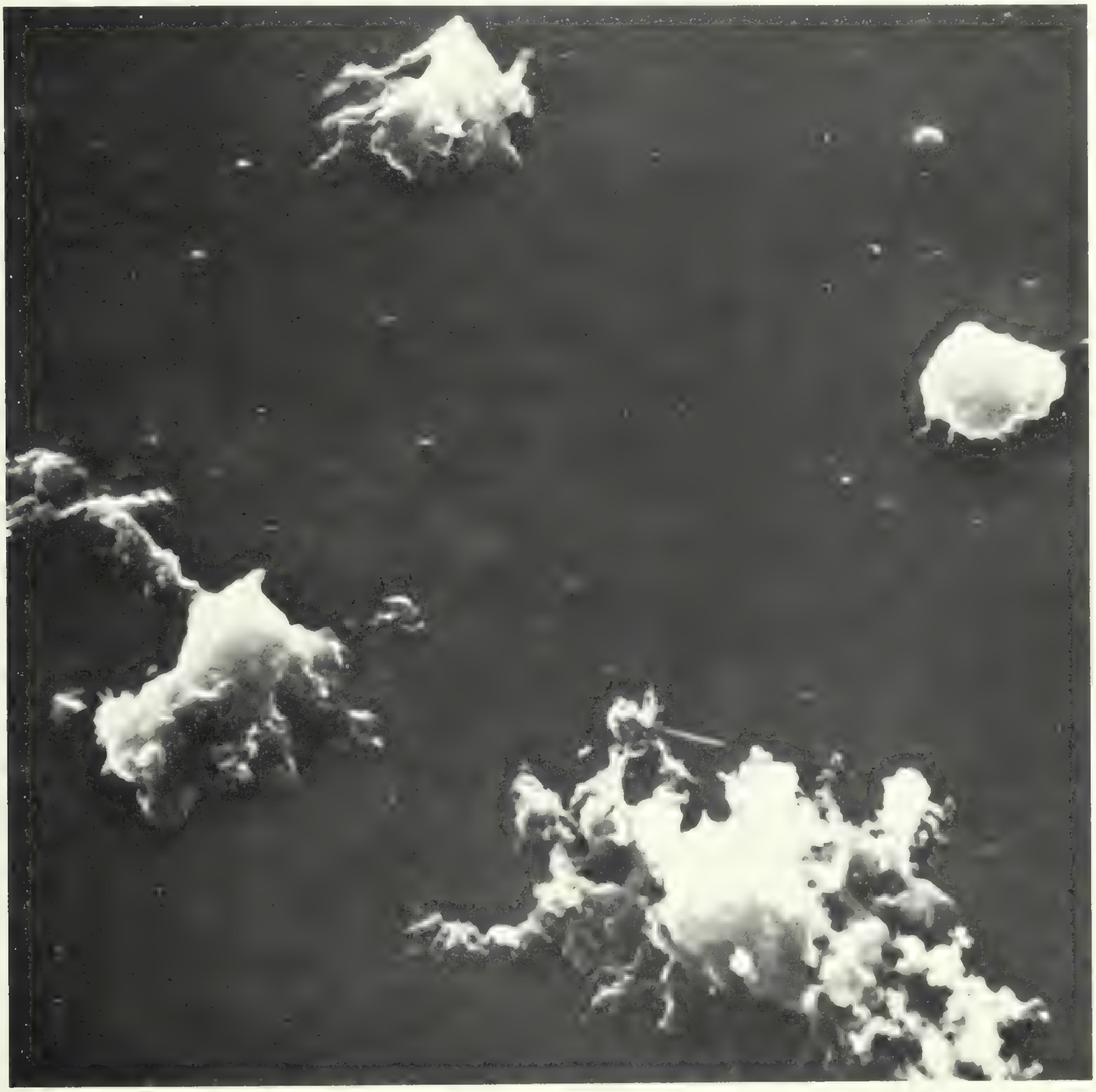


Figure 9. — A scanning electron micrograph shows angular nature of solid primary particles and the aggregation of small particles into long, chainlike masses.

Particles are also formed by the mechanical action of turbulent forces present in the fire zone. These forces simply break up the fire-weakened fuel and lift small pieces into the heated air column over the fire. Initially, mechanically formed particles are fewer in number but usually are larger and have more mass than the chemically produced ones. Figure 10 shows this type of particle.

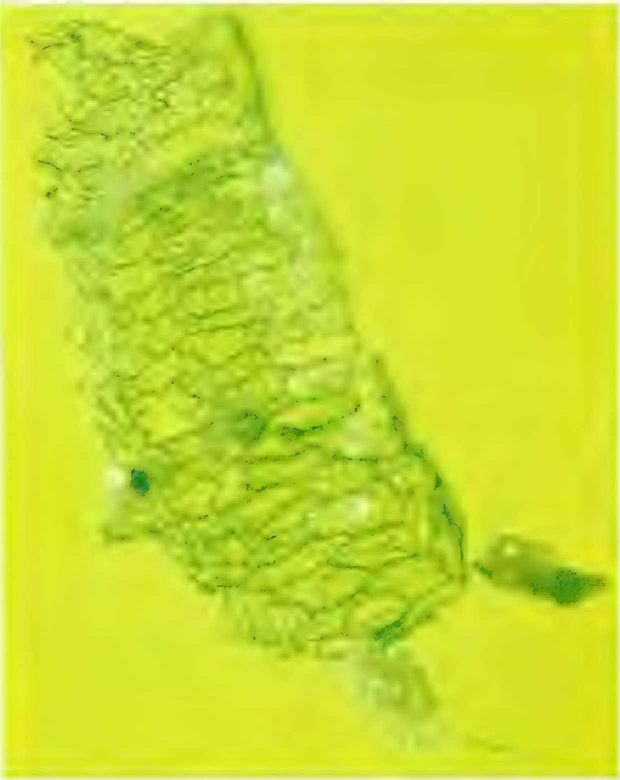


Figure 10. — A large, mechanically formed particle. Notice that plant structures can still be identified.

Mass Distribution

Particles are produced in a wide range of sizes. The amount of particulate matter in each size category is called the size distribution, which can be expressed as mass or number of particles. We report both mass and number distributions because some effects are more closely related to mass distribution and others to number distribution. In addition, no existing instrument can measure the full range of sizes. Expensive instruments are available to measure very small particles; they usually record number distributions. Commonly available instruments for measuring larger particles usually record mass distributions.

A particle's mass, in combination with its size and shape, determines its aerodynamic size. Aerodynamic size equates an irregular shape to a sphere and can be much different than physical size. The solid and liquid particles in figure 8, although of obviously different physical sizes, are the same aerodynamic size. Aerodynamic size is more closely related to particulate matter dispersion and respiratory effects, while physical size is more related to visibility effects.

We sampled the aerodynamic mass size distribution of particulate matter from several experimental backing fires in slash pine and palmetto-gallberry fuels of Georgia and Florida. About 70 percent of the particle mass from the slash pine fires was less than 0.4 micron in diameter, and 95 percent was less than 1 micron. Similar results have been reported from other studies in the United States and elsewhere. In the smoke from Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) fires in the Northwest, 69 percent of the particle mass was found to be less than 0.3 micron and 82 percent less than 1 micron (Sandberg and Martin 1975). Additional information collected with a scanning electron microscope showed that most single, spherical particles were about 0.1 micron in diameter. Particulate matter in the smoke from burning rice residue was found to have mass median diameters that range from 0.1 to 0.3 micron (Goss and Miller 1973). Reports from Australia and England show that woods smoke particles are about 0.1 micron in diameter (MacArthur 1966 and Foster 1960).

Number Distribution

A recently developed instrument has given us the opportunity to measure the lower range of particle distribution. It was used in field experiments during the 1974-75 fire season. These distributions (fig. 11) are from fires in longleaf-slash pine needles in Louisiana, a sawgrass stand in the Everglades of Florida, light brush under a loblolly pine stand in Georgia, and light brush under a loblolly pine stand in North Carolina. Samples were collected at distances from the fire site of 0.3 mile to 3.5 miles, except in Florida where the distance was 12 miles.

Certain properties of the size distributions of particles can be discovered by comparing the number distributions (fig. 11) with the mass distributions (fig. 12). Merging values from the two distributions, we found that the average diameter of particles in forest fire smoke is approximately 0.1 micron, and that this average is approximately the same for fires in all fuel types.

In general, only particles smaller than 10 microns can be expected to pose problems at distances greater than ½ to 1 mile from the source of production. Particles larger than 10 or 20 microns will usually be removed from the atmosphere by gravitational forces within this distance. There are, of course, exceptions caused by extreme

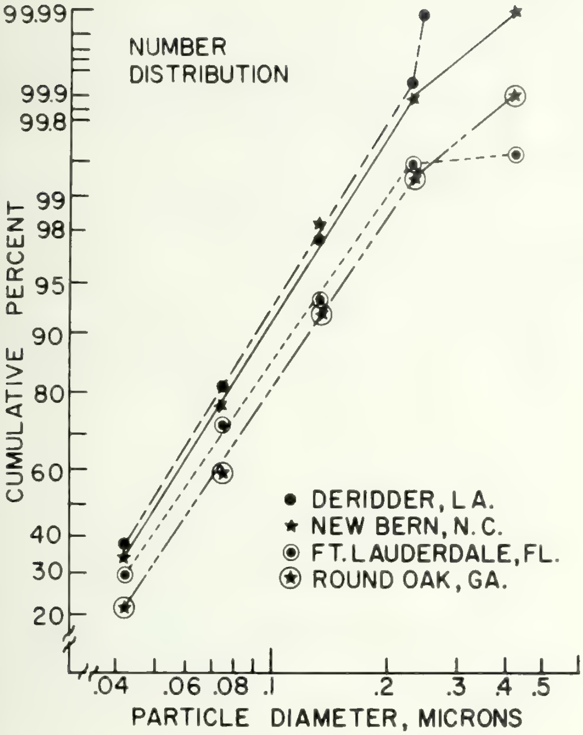


Figure 11. — Size distribution for particles smaller than about 0.5 micron. Distribution is based on numbers of particles.

windspeeds or by specialized particle growth conditions high in the atmosphere. Particles found by aircraft samplings of forest fire smoke plumes are rarely larger than 10 microns.

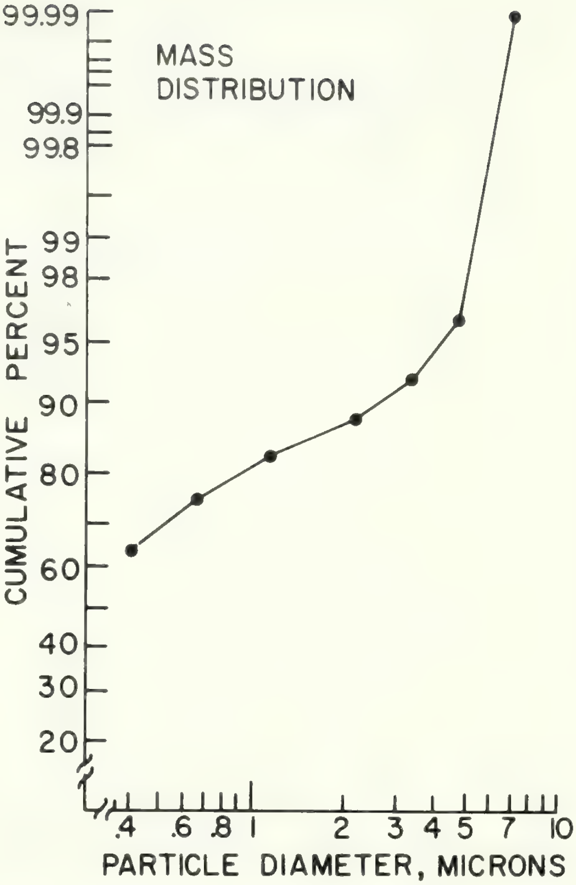


Figure 12. — Distribution of particles larger than 0.4 micron. Distribution is based on mass.

LITERATURE CITED

Ay, J. H., and M. Sichel

1976. Theoretical analysis of NO formation near the primary reaction zone in methane combustion. Combust. & Flame 25(1):1-15.

Balchum, Oscar J.

1973. Toxicological effects of ozone, oxidant, and hydrocarbons. Proc. Conf. Health Effects Air Pollut.:489-503. NAS-NRC, Washington, D.C.

Bartlett, Donald, Jr.

1973. Effects of carbon monoxide on human physiological processes. Proc. Conf. Health Effects Air Pollut.:103-126. NAS-NRC, Washington, D.C.

Brown, Arthur A., and Kenneth P. Davis

1973. Combustion of forest fuels, p. 155-182. *In* Forest fire: control and use. 2d ed. McGraw-Hill Book Co., Inc., New York.

Browne, F. L.

1963. Theories of the combustion of wood and its control. USDA For. Serv., For. Prod. Lab. Pap. 2136, 59 p. Madison, Wis.

Engel, Ronald E., H. Wilfried Goerke, Rauf Saygin, and others

1971. Air quality criteria for particulate matter. NATO, Comm. Challenges Modern Soc., N. 8, 257 p. Brussels, Belgium.

Evans, Leslie F., Nicholas K. King, David R. Packham, and others

1974. Ozone measurements in smoke from forest fires. Environ. Sci. & Tech. 8(1):75-76.

Foster, W. W.

1960. The size of wood smoke particles. Int. J. Air Pollut. 3:89-96.

Goss, J. R., and G. E. Miller, Jr.

1973. Study of abatement methods and meteorological conditions for optimum dispersion of particulates from field burning of rice straw. Spring open field burning trials. U.S. Dep. Commer., Natl. Tech. Inf. Serv. PB-235-796, 47 p. Springfield, Va.

Horvath, Steven M.

1973. Effects of carbon monoxide on human behavior. Proc. Conf. Health Effects Air Pollut.:127-144. NAS-NRC, Washington, D.C.

Hueter, F. Gordon, H. Wilfried Goerke, Necip A. Berksan, and others

1973. Air quality criteria for nitrogen oxides. NATO, Comm. Challenges Modern Soc., N. 15, 213 p. Brussels, Belgium.

Hueter, F. Gordon, H. Wilfried Goerke, Necip A. Berksan, and others

1974. Air quality criteria for photochemical oxidants and related hydrocarbons. NATO, Comm. Challenges Modern Soc., N. 29, 365 p. Brussels, Belgium.

Hueter, F. Gordon, H. Wilfried Goerke, Ayson Muezzinoglu, and others

1972. Air quality criteria for carbon monoxide. NATO, Comm. Challenges Modern Soc., N. 10, 264 p. Brussels, Belgium.

Jones, P. W.

1975. Final report on leaf burning emission program. Battelle Columbus Laboratories, Contract No. 63-02-1409, Task 28, Columbus, Ohio.

Kramer, Paul J., and Theodore T. Kozlowski

1960. Physiology of trees. McGraw-Hill Book Co., Inc., 642 p., New York.

MacArthur, D. A.

1966. Particle sizes in bush fire smoke. Aust. For.:274-278.

Murty Kanury, A.

1972. Ignition of cellulosic solids - a review. Fire Res. Abstr. & Rev. 14(1):24-52.

National Academy of Sciences

1972. Particulate polycyclic organic matter. Work performed pursuant to Contract No. CPA 70-42 with Environmental Protection Agency. 361 p., Washington, D.C.

National Academy of Sciences

1973. Sulfur oxides and particles. Proc. Conf. Health Effects Air Pollut. (Sess. 2):173-460. Washington, D.C.

National Academy of Sciences

1975. Air quality and stationary source emission control. Prepared for Committee on Public Works, U.S. Senate, 94th Congress, 1st Session. 909 p. Washington, D.C.

Sandberg, D. V., and R. E. Martin

1975. Particle sizes in slash fire smoke. USDA For. Serv. Res. Pap. PNW-199, 7 p. Pac. Northwest For. & Range Exp. Stn. Portland, Oreg.

Shy, Carl M.

1973. Human health consequences of nitrogen dioxide: a review. Proc. Conf. Health Effects Air Pollut.:363-405. NAS-NRC, Washington, D.C.

CHAPTER III

AIR QUALITY ADMINISTRATION

by

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This Chapter reviews the legislation and regulations passed to maintain air quality. It also introduces a voluntary decision procedure proposed for forestry smoke management.

THE FEDERAL CLEAN AIR ACTS

Interest in Federal clean air legislation began to accelerate in 1955 when Congress provided for investigations into the nature and extent of the Nation's air pollution problems. With the passage of the Clean Air Act of 1963 (PL 88-206), Congress encouraged the first air pollution abatement programs by providing Federal funds to assist in State and local control efforts and by establishing limited authority to abate interstate air pollution. Amendments to the 1963 Act in July 1967 increased the powers of the Secretary of the Department of Health, Education, and Welfare to implement air pollution abatement programs anywhere in the United States. The amendments included provisions to:

Request injunctions to abate emissions

Designate air quality control regions

Establish air quality standards for the above regions in the absence of effective State action

Enforce the above standards

Establish interstate air quality planning commissions; in lieu of action by the affected States (Stern 1971).

The Clean Air Act of 1970 greatly increased Federal powers and responsibilities. Section 101, paragraph (b) of the 1970 Clean Air Act lists as its purpose:

"To protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population" (U.S. Code: 42 U.S.C. S. 1857), while at the same time encouraging additional State and local regulations.

A REVIEW OF KEY SECTIONS OF THE 1970 CLEAN AIR ACT (PL 91-604) APPLICABLE TO FORESTRY PRESCRIBED BURNING

SECTION 108: AIR QUALITY CRITERIA AND CONTROL TECHNIQUES

The Environmental Protection Agency Administrator is directed to identify and publish a list of air pollutants. Included in this list is particulate matter.

SECTION 109: NATIONAL AMBIENT AIR QUALITY STANDARDS

The EPA Administrator is required to establish national primary and secondary ambient air quality standards for the pollutants identified in Section 108. The primary standard is set at a level necessary to protect the public health, while the secondary standard is set at a level to protect the public welfare from any known or anticipated adverse effects of a pollutant. Table 6 lists the levels of pollutants thus far identified by the standards as being adequate to protect the public health and welfare.

Table 6. — National primary and secondary ambient air quality standards 1/

Pollutant	Type of standard	Averaging time	Frequency parameter	Concentration	
				µg/m 3	Ppm
Carbon monoxide	Primary and secondary	1 hr	Annual maximum 2/	40,000	35.0
		8 hr	Annual maximum 2/	10,000	9.0
Hydrocarbons (nonmethane)	Primary and secondary	3 hr (6 to 9 a.m.)	Annual maximum 2/	3/ 160	3/ 0.24
Nitrogen dioxide	Primary and secondary	1 yr	Annual arithmetic mean	100	0.05
Photochemical oxidants	Primary and secondary	1 hr	Annual maximum 2/	160	0.08
Particulate matter	Primary	24 hr	Annual maximum 2/	260	—
		1 yr	Annual geometric mean	75	—
	Secondary	24 hr	Annual maximum 2/	150	—
		1 yr	Annual geometric mean	4/ 60	—
Sulfur dioxide	Primary	24 hr	Annual maximum 2/	365	0.14
		1 yr	Annual arithmetic mean	80	0.03
	Secondary	3 hr	Annual maximum 2/	1,300	0.05

1/ Adapted from Federal Register (1971).
2/ Not to be exceeded more than once per year.
3/ As a guide in devising implementation plans for achieving oxidant standards.
4/ As a guide to be used in assessing implementation plans for achieving the annual maximum 24-hour standard.

SECTION 110: IMPLEMENTATION PLANS

Each State must develop and submit for Federal approval a comprehensive plan identifying the strategy that the State intends to follow in order to attain and maintain the National Ambient Air Quality Standards. A State may revise its State Implementation Plan (SIP) at any time and, in turn, may be required to revise its plan by the Environmental Protection Agency (EPA) if it is found to be substantially inadequate.

SECTION 113: FEDERAL ENFORCEMENT

This Section also provides for Federal enforcement of an SIP where violations appear to be caused by a State's failure to enforce its own SIP. The EPA can initiate court actions against polluters violating an applicable provision of an SIP.

SECTION 114: INSPECTIONS, MONITORING, AND ENTRY

Onsite inspection of emission sources is authorized (U.S. Environmental Protection Agency 1970).

STATE AND LOCAL AIR QUALITY REGULATIONS [1]

Most States have granted variances from air pollution control rules to valid forestry burning practices. This could be done under the provisions of the Clean Air Act because these operations have not been identified as a *major* source of particulate matter.

[1] Portions of this Section were contributed by Joan B. Boilen, Attorney, Legal Support Branch, U. S. Environ. Prot. Agency, Reg. IV, Atlanta, Ga., 1975.

When emissions from major sources are reduced, lesser sources may be expected to receive more attention. Control of major sources alone may not be sufficient to achieve local ambient standards. Then, reduction of emissions from minor sources may be required. Some southern States are bringing prescription burning under control by requiring permits, and some have specified certain conditions limiting open burning. A few counties have curtailed all open burning.

The following are examples of some of the more stringent State regulations affecting forestry prescription burning in the South:

> In Arkansas, open burning is prohibited within specified distances of certain population centers except for fires used for purposes of forestry management, provided fires are set and burned when winds are blowing away from populated areas.
>
> In Florida, open burning is allowed between 9:00 a.m. and 1 hour before sunset with permission of the State Division of Forestry, or at other times when allowed by the Division and when dispersion of air pollutants is reasonably assured.
>
> In Georgia, counties with populations exceeding 65,000 allow open burning only if adequate disposal facilities are not reasonably available. In all counties, no smoke of a shade darker than a No. 2 on a Ringelmann chart (a means by which opacity of smoke plumes is judged by visual observation) is permitted—except for a reasonable period to get the fire started.
>
> In South Carolina, open burning specifically for forestry management is excepted from a general ban when practices acceptable to the State Board of Health and Environmental Control are followed, and when no undersirable levels of pollutants are or will be created.
>
> In Tennessee, forestry prescription burning exceptions include provisions that no public nuisance is created, and that no land, air, or water traffic hazard is created. Distances from certain specified land-use areas (e.g., 1/2 mile from a secondary highway) are also imposed as restrictions on burning.

The importance of having an up-to-date knowledge of traditional State and local air quality regulatory requirements is evident from these examples. In addition, the forestry smoke manager needs firsthand knowledge of specific concerns in each Air Quality Control Region (AQCR) and in any Air Quality Maintenance Area (AQMA) where he works.

AIR QUALITY CONTROL REGIONS AND MAINTENANCE AREAS [2/]

The primary air quality administrative area is the Air Quality Control Region (AQCR). These areas were designated on the basis of geographical and meteorological considerations, as well as political boundaries. For this reason, they may transcend State or county borders.

Initially, in 1971 these AQCR's were classified Priority I, II, or III based upon existing air quality to assist States in planning. In each AQCR the sources of air pollution were identified and control measures adopted that, after analysis, were felt to be sufficient to provide for attainment of the National Ambient Standards upon implementation.

In 1973, a court decision required EPA to disapprove all State Implementation Plans (SIP's) for not providing for maintenance of the ambient standards beyond the attainment date of mid-1975. The court held that SIP's had addressed the growth of pollution sources and their related air emissions only until the time when standards would be attained, and not beyond. Further, the court made clear the Clean Air Act required the development of a plan that included provisions for continuing attainment and maintenance of the ambient standards well beyond the attainment date. In response to the court's decision, EPA developed procedures for each State to use in assessing the maintenance issue. Each State was asked to review the air quality within its jurisdiction and identify those areas (usually counties) that, due to anticipated growth, had the potential to violate the ambient standards during the forthcoming 10-year period. These areas were identified as Air Quality Maintenance Areas (AQMA's).

In most cases, the area designated as an AQMA is only a portion of an AQCR. Usually the AQMA is urban as well as the surrounding area expected to be affected by the same growth potential. Designation of the AQMA's was completed in September 1975. Much emphasis has been placed on these AQMA's by each State in their reviews of growth and its impact on air pollution. The States are assessing strategies that, upon application, will provide continuous maintenance of the ambient standards.

[2/] Portions of this Section were contributed by William M. Burch, Chief, Air Strategy Dev. Sect., Air Programs Branch, Air and Hazardous Mater. Div., U.S Environ. Prot. Agency, Reg. IV, Atlanta, Ga., 1975.

PREVENTION OF SIGNIFICANT DETERIORATION

Additional court decisions involving interpretation of the Clean Air Act resulted in the development of the EPA program to prevent significant deterioration (PSD) of air quality. The Administrator put this program into effect on December 5, 1974 (Federal Register 1974).

These PSD regulations combined the concept of area classification with new source review procedures and the application of best available control technology. The preconstruction review of all new and modified sources now including 19 major categories (but not forestry burning) is designed to prevent their violating allowable increments of deterioration and to assure the employment of best available control technology (Federal Register 1975). States are being encouraged to accept a delegation of authority to implement this review process fully.

While the regulations are directed to specifically named stationary sources, their importance to other sources lies in area classification by classes.

The regulations stated that, effective January 6, 1975, all areas are designated Class II and restrict deterioration to that associated with normal, well-controlled growth. With the 1974 air quality regulations as a baseline, States may decide if areas should remain Class II or should be either Class I that restricts deterioration to a minimum, or Class III that levies no additional restrictions beyond State plan requirements and considers any deterioration as insignificant as long as no national standards are violated. These class designations differ from the priority classification discussed earlier in that they indicate levels of air quality to be maintained, whereas the priority classifications indicate the urgency to apply pollution abatement measures to the areas so designated.

A VOLUNTARY DECISION PROCEDURE PROPOSED FOR FORESTRY SMOKE MANAGEMENT[3]

Even though the main focus of air quality regulations has been on stationary and automotive sources of emissions, southern forest managers have sought a method by which they may voluntarily help to avoid unwanted environmental consequences from prescription burning. In the preceding sections of this Chapter, we have reviewed an evolving framework of air quality administration. In Chapter I we discussed alternatives to burning, and in Chapter II we examined the characteristics of forestry smoke likely to bear on future increased regulatory interest, locale by locale.

A single forestry burn will seldom be an important emitter more than a few hours on 1 day every 3 or 4 years. It may, however, contribute emissions of consequence to a given atmosphere when the pollution load is already high, or when concentrations temporarily exceed locally acceptable levels. Because they are based on long-term health studies, regulations and standards established for stationary and mobile sources of emissions do not lend themselves well to decision procedures for these transitory forestry sources. For example, standards are usually expressed as concentrations averaged over times longer than a forestry burn would last. Because of this, a time/concentration adjustment could be made which would still be within established standards; the adjusted concentration could, however, be intolerable when judged by other criteria such as highway safety or personal respiratory difficulties.

In some areas of the United States, carrying capacity of the atmosphere is estimated within certain boundaries. This approach is called the "Tank Concept" in that this supposed finite atmosphere is regarded as having limiting "walls" and a "lid." We have rejected this concept because it does not adequately represent actual dispersion, particularly in the initial stages.

Our proposal will be fully presented in Chapter VI, after discussions in Chapters IV and V on the important variables affecting the procedure. We believe the proposal will lend itself well to self-regulation or to agency administration. It emphasizes decisions for the single forestry burn, but also recognizes multiple contributions from other forestry burning or fixed sources. A major gain in air quality will be achieved in some locales if the procedures for multiple-source forestry burns are applied by mutual agreement between burners.

Currently the best available control technology (also used in many similar instances) is to limit the escape of particulate matter into the atmosphere, regardless of the size or chemical composition of the particulate matter. We have adapted this control technology to short-term or instantaneous concentrations.

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[3] Contributed by Southern Forest Fire Laboratory personnel who developed the Decision Logic presented in Chapter VI

Very small chemically reactive particles have a greater potential to impair health than large chemically inert particles. Regulatory agencies are placing increased emphasis on controlling more harmful components. Limiting strategies under development will thus likely be more specific.

While many tedious operations are needed for decisions in complex situations, the basic procedure involves just five main steps:

1. Predicting a smoke plume trajectory
2. Identifying key targets along this trajectory (in this text, targets denote locations where smoke concentrations are more likely to have unwanted effects; e.g.: an AQMA, a "sensitive" community, an airport, a road, a highway, a townsite, etc.)
3. Selecting a maximum acceptable particulate matter concentration for each key target identified
4. Determining the "background" pollutant level within the target area, then adding this to the prescribed fire concentration predicted to reach the zone where the target is identified
5. Comparing the maximum acceptable concentration in No. 3 with the total concentration in No. 4.

Selection of a maximum acceptable concentration in No. 3 above can be either as determined by a special ambient air quality requirement in effect or desired, or as dictated by a need to maintain a certain level of visibility. In the procedure described in Chapter VI, either type of value can be selected by the decisionmaker. There is an implication in the literature that public complaints are more closely associated with visibility reductions and with effects of visibility impairment on highway and air traffic safety. Decisionmakers arriving at acceptable concentrations may also be influenced by the current indication that visibility-determined concentrations for total suspended particulate matter are more stringent than those suggested by published human health effects (U.S. Department of Health, Education, and Welfare 1969).

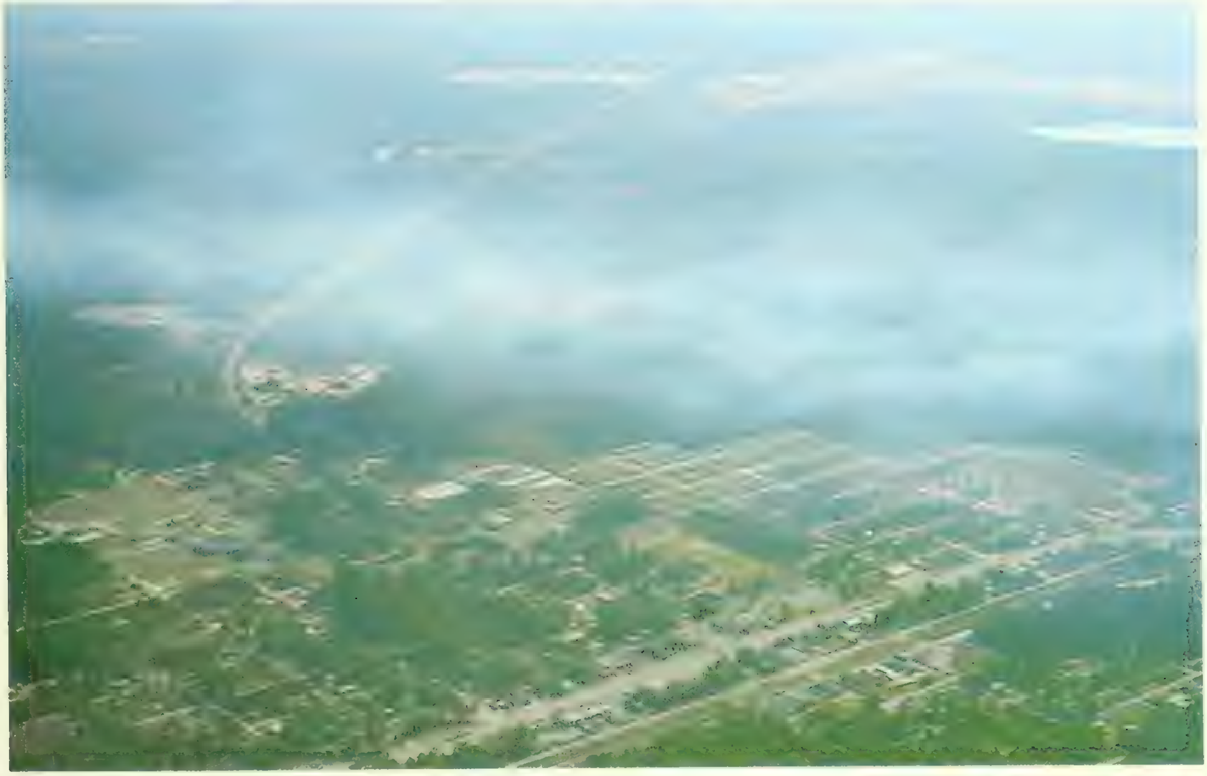

Figure 13. — A first step in smoke management is to identify potential targets — areas that might be adversely affected by the smoke from a prescribed burn.

LITERATURE CITED

Federal Register

1971. National primary and secondary ambient air quality standards. Fed. Regist. 36(84): 8186-8201.

Federal Register

1974. Approval and promulgation of implementation plans. Fed. Regist. 39(235):42510-42517.

Federal Register

1975. Approval and promulgation of implementation plans. Fed. Regist. 40(176):42011-42012.

Stern, Arthur C.

1971. Air and water pollution quality standards. Part 1: Air pollution standards, p. 4-1 through 4-22. *In* Herbert F. Lund (ed.), Industrial pollution control handbook. McGraw-Hill Book Co., Inc., New York.

U.S. Department of Health, Education, and Welfare

1969. Air quality criteria for particulate matter. Natl. Air Pollut. Control Adm. Publ. No. AP-49, 211 p. Natl. Air Pollut. Control Adm., U.S. Dep. Health, Educ., and Welfare, Washington, D.C.

CHAPTER IV

FUELS, FIRE BEHAVIOR, AND EMISSIONS

by
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This Chapter prepares you to predict the amount of particulate matter emitted and the rate of heat release from deliberate burning of forest fuel. Making these predictions requires estimates of the amount of fuel that will burn, the rate at which fire will spread, the amount of particulate matter that evolves per ton of fuel burned (called emission factor), and the heat yield of the fuel.

The material presented is organized as follows: variables affecting emissions and fire phases, heat release rate, emission rate, specific information by fuel types, and a conclusion. Although many fuel complexes are present in the Southeast, only the major types in which most of the prescription burning is done will be discussed. The identification of each fuel type is generally based on its vegetative cover and, to some extent, on the ecological province it occupies. The major fuel types discussed in separate sections are: grasses, pine needle litter, palmetto-gallberry, light brush, and pine logging debris.

VARIABLES AFFECTING EMISSIONS AND FIRE PHASES

Emissions of particulate matter are influenced by many variables as are fire phases. These are reflected in fuel loading, rate of spread, burning method, and combustion stage.

FUEL LOADING

It is important to understand the difference between *total* fuel and *available* fuel. *Total* fuel is the entire accumulation of vegetative matter, living or dead, that could possibly burn if properly conditioned. *Available* fuel is that portion of the total fuel that will be consumed by a fire during the burning period following ignition. While available fuel is needed in the emission rate and heat release rate equations, total fuel must be estimated before the available value can be calculated.

Three layers of litter will eventually develop on an undisturbed forest floor: a top litter layer (L), a fermentation layer (F), and a humus layer (H). When sampling, the two upper litter layers (L + F) can be grouped. These L + F layers account for most of the fuel consumed during prescription burns (Hough 1968). During droughts, considerable humus can also burn. Live vegetation in the understory must also be accounted for since it will be consumed in varying degrees, depending on the burning conditions.

RATE OF SPREAD

Rate of fire spread must be known to compute *particulate matter emission rate* and *heat release rate to the atmosphere* from prescribed fire.

The rate at which fire advances through a forest fuel usually depends on windspeed and on size, arrangement, and moisture content of the surface litter and understory fuel. An exception is when the fire is backing against the wind. In that case differences in windspeed have a negligible effect on spread rate, and a windspeed of zero should be used when entering the rate of spread tables.

Fire spread rates vary by fuel type because of differences in fuel type and arrangement. They are, therefore, discussed individually in the Guidebook.

BURNING METHOD

The burning method employed will depend upon the kind of area to be burned and the burning conditions. There are four main categories of burning method:

> *Backing fires* are those that are ignited on the downwind side of an area and permitted to spread (or "back") against the wind.

Heading fires are ignited on the upwind side of an area and permitted to spread (or "head") with the wind.

Sometimes, *backing* or *heading fires* are ignited in strips and allowed to burn together.

Ring fires are ignited on all sides of an area to be burned.

Area-ignited fires or *simultaneous-ignition fires* are those that are ignited in many places at about the same time to result in many small fires burning together.

Often, combinations of these categories are used.

Burning is generally done in two kinds of areas. In the first, a tree overstory exists and considerable understory and/or litter are to be removed. The fuel is generally natural plant accumulations that increase with time, although logging residue from thinnings may also be present. In the second kind of area a tree overstory no longer exists, but there is fuel on the ground. This fuel results from clearcut logging or brush clearing.

When burning under a tree overstory, timber managers must be sure their fires do not seriously damage or destroy crop trees. A manager usually waits for those days when winds are likely to remain steady for the burning period. He can then ignite the downwind side of his area and allow the fire to back slowly against the wind. If fuel loading is not excessive, intensity of a heading fire may be acceptably low.

When burning areas free of an overstory, there is obviously no need for concern about damage to an overstory. The main purpose of such burns is to consume as much fuel as possible on the area. Only precautions to prevent fire escape, to minimize air pollution downwind, to avoid soil damage and unwanted runoff of ash, etc., need be considered. High-intensity heading fires are generally used when the fuel is dispersed over the area. Such fires will usually jump gaps in fuel continuity.

There are times, especially in land-clearing operations, when much of the fuel exceeds 2 inches in diameter. If disposal of the large material by burning is desired, some form of piling is necessary. Concentrating the fine fuel with the large, allowing the entire mass to dry, and igniting the pile perimeters quickly to get rapid heat buildup will permit the large fuel elements to be ignited and eventually consumed.

Burning method affects rate of fire spread, rate of particulate matter emission, and amount of fuel consumed. In heading fires, a relatively large amount of fuel is consumed during the residual combustion stage, and more particulate matter is produced per unit of fuel burned.

COMBUSTION STAGES

We will discuss combustion in two main stages: *advancing-front stage* and *residual stage.* These stages may be broken down into substages to further characterize the fire behavior. For example, the *advancing-front stage* is usually a *flaming front,* but can also be a *smoldering front.* For the burning situations covered in this Guidebook, only the two main stages are important to determining separate emission factors (EF) and emission rates (ER) due to marked differences in quantities of particulate matter emitted in these stages.

FIRE PHASES

For convenience, we have separated fires into two phases: *convective-lift phase* and *no-convective-lift phase.* The *convective-lift phase* is when most emissions are entrained into a definite convection column because of heat being released from the fire. The *no-convective-lift phase* is when most emissions are not entrained into a definite convection column. Heat release rate will be of consequence to the plume rise of the *convective-lift phase,* but of no consequence to the *no-convective-lift phase.*

MINIMIZING DURATION OF THE NO-CONVECTIVE-LIFT FIRE PHASE

Long-duration residual combustion involves humus, organic soil, and large fuel elements such as stumps, snags, and logs. Decaying stumps and snags exceeding 10 inches in diameter contribute most to long-duration residual combustion. Large pieces of sound wood are not easily ignited during the relatively brief exposure to the flaming front of a prescribed fire. When ignition does occur, the rapid departure of reinforcing heat from surrounding sources causes quick flameout, and smoldering in sound wood is short lived. This Guidebook does not address the problem of long-duration residual combustion in detail because the great variability does not now permit a standard handling procedure. There are, however, some safeguards that can be observed to minimize troublesome emissions during the associated no-convective-lift phase of fires.

Rate of stump deterioration following timber cutting was observed in the Coastal Plains of Georgia (unpublished data, Southeastern Forest Experiment Station). Data from this study permit estimation of the extent of rot in stumps if the time of cutting is known:

Year after cutting	Depth of decay (Inches)
1	0.5
2	1.5 – 2.5
3	4.0 – 5.0
4	6.0

To minimize the amount and duration of residual combustion, take these actions:

Fell dead snags.

In cutting operations, keep stump height as low as possible to maximize moisture content of decaying stumpwood and speed decay.

Burn only when stump moisture content is high, as soon after a heavy rainfall as possible.

Scatter large, sound wood material.

As necessary, provide for mopup.

TOTAL LITTER LAYER MOISTURE CONTENT

Fuel moisture is constantly changing, and the changes must be monitored. Both wetting and drying moisture curves for 10-hour timelag fuels are contained in the National Fire-Danger Rating System (NFDRS) (Deeming and others 1972), but they do not apply to pine needle litter. The *wetting curves* are based on moisture absorbed by wood dowels that respond much slower than does pine needle litter. The *drying curves* approach 10 to 15 percent moisture content in about 7 days—lower than measured moisture contents in heavy slash pine litter layers 7 days after a rain. Palmetto-gallberry, grass, and pine needle litter types all need more accurate litter moisture estimates. More appropriate curves were, therefore, developed using data from experimentally burned plots in the South.

Multiple-regression analysis showed that total litter layer moisture content could be predicted with acceptable accuracy from days since rain and total litter layer dry weight (Hough 1976). In the presence of these variables, relative humidity did not improve predictions. Using Hough's (1976) equations, table 7 was developed to show rates of drying for litter. To enter the table, one must know the age of rough and yesterday's total litter layer moisture content. The value shown in the table is subtracted from yesterday's value to estimate today's total litter layer moisture content.

During wet, rainy periods forest litter moisture content increases. Moisture retention capacity of total forest litter layers has been found to be up to 300 percent of dry weight (Swank and others 1972, Metz 1958, Helvey 1964, Van Wagner 1970). Metz found this maximum moisture content only after prolonged rainfall, indicating the importance of rainfall duration. This need was also shown by Paul,[4] who found that maximum water uptake for pine litter occurs in 10 to 12 hours. A single curve of total litter layer moisture content versus duration of precipitation was used to construct a table that gives a reasonable estimate of moisture content *increases* in the litter fuel bed (table 8).

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[4] Paul, James T 1967 Influence of rate of rainfall on pine litter moisture content Unpublished report Southeast For Exp Stn , Macon, Ga

Table 7. — Daily correction to the total litter layer moisture content for drying

Age of rough (years)	Yesterday's total litter layer moisture content (percent)																
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-55	56-65	66-89	90-109	110-129	130-164	165-199	200-200+
								Percent									
1 to 2	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-13	-18	-25	-40	-60	-75	-80
3 to 10			0	-1	-2	-3	-4	-5	-6	-7	- 9	-12	-16	-25	-50	-70	-75
11 to 25					0	-1	-2	-3	-4	-5	- 6	- 9	-12	-17	-40	-65	-70

Table 8. — Correction to total litter layer moisture content for wetting due to precipitation

Precipitation duration (hours)	Yesterday's total litter layer moisture content (percent) [1]				
	10-30	31-50	51-70	71-90	91+
			Percent		
1	+ 75	+ 55	+ 35	+ 15	0
2	+100	+ 80	+ 60	+ 40	+ 25
3	+120	+100	+ 80	+ 60	+ 45
4-5	+135	+115	+ 95	+ 75	+ 60
6-8	+150	+130	+110	+ 90	+ 75
9-12	+165	+145	+125	+105	+ 90
12-24	+220	+200	+180	+160	+145

[1] A value of 250 percent is the practical maximum that should be used. If yesterday's total litter moisture content, plus the correction for precipitation exceeds 250, enter 250 on records.

To use table 8, all that is needed is duration of rainfall and a value for yesterday's total litter layer moisture content. The value taken from the table is added to yesterday's total litter layer moisture content to give the moisture content of the layer today. Rainfall duration should be obtained from nearby weather stations, or from fire-danger rating stations that maintain rainfall duration records. A form (table 9) was designed to keep track of daily changes in total litter layer moisture content. This record should be started when there has been abundant rainfall for 8 or more hours so that an initial value of 250 percent for today's litter moisture can be assigned opposite the appropriate date and fuel loading class. Should a time of year be selected for beginning to track the total litter layer moisture when the chance for having 8 hours of continuous rain is remote, pick a day when at least 0.25 inch of rainfall occurs and assign a litter moisture value of 100 for that day.

If a number of stands have different ages of rough and are being considered for prescription

Table 9. — Daily record of total litter layer moisture content

Day of month	Age of needle rough	Correction for daily drying	Precipitation			Correction due to rain duration	Yesterday's litter moisture content	Today's total litter moisture content
			Begin	End	Duration			
	Years	Percent	Time	Time	Hours	Percent	Percent	Percent
1	1- 2	—				+		
	3-10	—				+		
	11-25	—				+		
2	1- 2	—				+		
	3-10	—				+		
	11-25	—				+		
3	1- 2	—				+		
	3-10	—				+		
	11-25	—				+		
4	1- 2	—				+		
	3-10	—				+		
	11-25	—				+		
Daily record continues to end of month								

burning, the daily drying rates will have to be maintained for each age class.

Steps and tables needed to determine total litter layer moisture content are:

1. Obtain records of daily rainfall duration from the nearest weather station or fire-danger rating station.

2. Beginning with the day of interest (today), search the records backward until a day is found on which rainfall duration exceeded 8 hours or at least ¼ inch of rain fell.

3. Locate that date on table 9 and enter 250 or 100 in the "Today's" column for that day's litter moisture.

4. Compute daily change in fuel moisture using instructions found on that form until today's date is reached. After these initial calculations are completed, it is suggested that daily calculations of total fuel moisture be made to maintain a current record.

5. When rain has fallen in the past 24 hours, go directly to Step 7. When it has not, go to Step 6.

6a. Record age of rough: ______ years.

b. Obtain yesterday's total litter layer moisture content from table 9.

c. Read correction factor due to drying from table 7.

d. Record factor in correction for daily drying column opposite today's date on table 9.

e. Subtract drying correction from yesterday's litter moisture.

f. Record answer in today's total litter moisture content column on table 9.

7. To increase yesterday's total litter moisture content by a correction factor for rain:

a. Record rain duration for past 24 hours: ______ hours.

b. Obtain yesterday's litter layer moisture content from table 9: ______ percent.

c. Read correction for rain in table 8.

d. Record correction due to rain duration opposite today's date and proper age of rough on table 9.

e. Add rain correction to yesterday's litter moisture.

f. Record answer in today's total litter moisture content column on table 9.

HEAT RELEASE RATE TO THE ATMOSPHERE

The rate of heat released to the atmosphere (HRR) by flames in an advancing-front combustion stage is needed to determine how high a smoke plume will rise during the convective-lift phase of the fire. Heat released from the residual stage of combustion is expected to be of importance in some situations, but is only negligible for those situations covered in this Guidebook.

The total heat of combustion of ovendry forest fuel burned in a bomb calorimeter averages 8,600 British thermal units (Btu) per pound and is a maximum value. Considerable heat is lost when these fuels are burned in the forest in their natural state. There, heat yield varies from 5,000 to 7,000 Btu. Losses are due to such phenomena as incomplete combustion, radiation, and the presence of moisture in the fuel. Brown and Davis (1973) report that 6,300 Btu is a good average for fuel conditions and types of fire encountered when prescription burning southern fuels. Further details will be covered in the *Forestry Smoke Management Sourcebook.*

The calculations for heat release rate (HRR) are:

1. To simplify the heat release rate equation and provide the dimensional units used in Chapters V and VI, we have determined a factor that includes the heat yield constant and converts from English to metric units—0.0012.

2. The heat release rate equation with this conversion factor is:

$$\mathrm{HRR} = 0.0012\, y_A\, wrL \qquad (1)$$

where HRR = heat release rate to the atmosphere in megacalories per second

y_A = fractional part of available fuel involved in the advancing-front combustion stage (range 0.01 to 1.00)

w = weight of available fuel in tons per acre

r = rate of spread in feet per minute

L = length of fire front in feet.

PARTICULATE MATTER EMISSION RATE

The particulate matter emission rate (ER) is the weight of suspended particulate matter produced per unit length of line per unit of time. This rate is needed to determine how much will be transported and dispersed to targets downwind from a burn. An emission factor (EF) will be used in this calculation. Each fuel type has been assigned a constant emission factor that reflects its unique characteristics. Within fuel types, fuel arrangement and moisture patterns are known to influence the EF. We do not have sufficient data to calculate such variations precisely, and the calculations would be cumbersome.

The manner in which particulate matter evolves from a prescription burn can differ measurably, depending upon available fuel and the manner of burning. All backing fires, and those heading fires burning on areas having low fuel loadings (1- to 2-year-old roughs), consume most of the fuel in the advancing-front combustion stage. However, heading fires in older roughs or in broadcast logging debris consume only 50 to 80 percent of the fuel during the advancing-front combustion stage. The available fuel remaining in heading fires is consumed in the residual combustion stage. In the case of heading fires in older roughs and logging debris, there is enough heat in the advancing-front combustion stage to entrain part of the residual stage emissions into a convection column; after the heat diminishes, emissions from the residual combustion stage become associated only with the no-convective-lift fire phase.

Contributions of emissions from the two combustion stages to the convective-lift fire phase and to the no-convective-lift fire phase are summarized by fuel type and burning method (table 10). More detailed information on emission factors (EF) is in separate sections to follow for each fuel type.

Table 10. — Contribution of emissions from combustion stages to fire phases

Fuel type and burning method	Fire phases	
	Convective-lift (CL) phase	No-convective-lift (NCL) phase
Grass with pine overstory:		
all burning methods	Advancing-front stage EF = 15 lb/ton	None
Pine needle litter and/or light brush with age of rough 2 years and less:		
all burning methods	Advancing-front stage EF = 50 lb/ton	None
Pine needle litter and/or light brush with age of rough more than 2 years:		
backing fires	Advancing-front stage EF = 50 lb/ton	None
heading fires	Advancing-front stage EF = 50 lb/ton and Residual stage EF = 180 lb/ton	Residual stage EF = 180 lb/ton
Palmetto-gallberry with age of rough 2 years and less:		
all burning methods	Advancing-front stage EF = 25 lb/ton	None
Palmetto-gallberry with age of rough more than 2 years:		
backing fires	Advancing-front stage EF = 25 lb/ton	None
heading fires	Advancing-front stage EF = 25 lb/ton and Residual stage EF = 125 lb/ton	Residual stage EF = 125 lb/ton
Unpiled logging debris:		
all burning methods	Advancing-front stage EF = 35 lb/ton and Residual stage EF = 180 lb/ton	Residual stage EF = 180 lb/ton

A factor of 570 is needed to convert from the familiar English units (pounds, acres, feet) used to describe our fuel, fire movement, and emission factor (EF) to the metric units needed in the emission rate (ER) dispersion equation in Chapters V and VI.

The equation for the advancing-front combustion stage particulate matter emission rate (ER_A) is:

$$ER_A = 570\, y_A wrEF_A \tag{2}$$

where ER_A = particulate matter emission rate in micrograms per meter-second

y_A = fractional part of available fuel involved in the advancing-front combustion stage (range 0.01 to 1.00)

w = weight of available fuel in tons per acre

r = rate of fire spread in feet per minute

EF_A = emission factor in pounds per ton for the advancing-front combustion stage.

The particulate matter emission rate (ER_R) for the residual combustion stage can be calculated in the same manner as for the advancing-front stage of combustion:

$$ER_R = 570\, y_R wrEF_R \tag{3}$$

where ER_R = particulate matter emission rate in micrograms per meter-second

y_R = fractional part of available fuel remaining to be involved in the residual combustion stage (or $1 - y_A$)

w = weight of available fuel in tons per acre

r = rate of fire spread in feet per minute

EF_R = emission factor in pounds per ton for the residual combustion stage.

For the convective-lift phase of heading fires where the total emissions must include those from both the advancing-front stage and the residual stage of combustion, a total emission rate is calculated as follows:

$$ER_{A+R} = ER_A + ER_R \tag{4}$$

Fuel types are discussed individually in the following sections. Since all of the referenced tables must be used in Chapter VI, they are presented therein for convenience of users, and will only be cited here to avoid repetition and save space.

GRASS WITH PINE OVERSTORY FUEL TYPE

DESCRIPTION

Loblolly, slash, and longleaf pines in the South are normally associated with various grasses, most of which form bunches rather than turf.

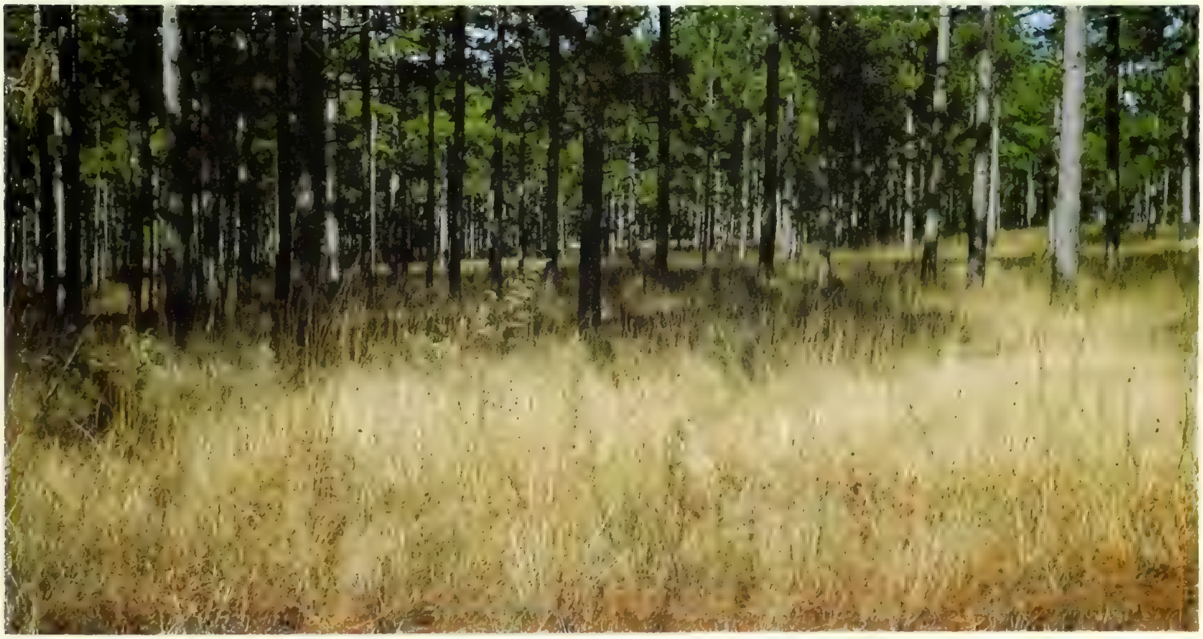

Figure 14. — Grass with pine overstory fuel type.

Grasses of the genus *Andropogon*—including broomsedge (A. *virginicus* L.), little bluestem(A. *scoparius* Michx.), and slender bluestem (A. *tener* Muhl.)—are dominant on all of the moist sites where longleaf has been succeeded by slash and loblolly pines, or where sites have been extensively disturbed by cultivation or site preparation such as disking, chopping, and bedding (Grelen 1962). On drier, sandy sites where longleaf pines predominate, wiregrass (*Aristida* spp.) dominates the site.

Where grass makes up a significant portion of the total fuel loading (estimated to exceed 50 percent by weight), and the presence of shrubs is insignificant, the fuel type will be designated "grass." Where a dense pine overstory exists, the fuel type is considered the same as a "pine needle litter type" after age of rough is more than 1 year.

FUEL LOADING

Grass fuels in forested stands are unique. The greatest accumulation occurs after the first growing season following a fire and continues to decrease thereafter. The decrease is due to the smothering effect of accumulating needles shed from a pine overstory and the shading effect of a developing brush understory. Total grass accumulation in tons per acre is presented in table VI-F-1, page 105, for easy use. For grass, available fuel will be considered equal to total fuel. The available fuel in any pine needle accumulation must also be estimated (table VI-F-5, page 109; or table VI-F-6, page 110; and table VI-F-7, page 111).

EMISSION FACTOR

Evidence available from the experimental burning of many grass species suggests an emission factor of 15 (pounds of particulate matter per ton of fuel) for prescribed burning with heading or backing fires. We are assuming that most of this burning will take place when fuel moisture is between 4 and 15 percent (dry basis), and that all fuel is consumed during the advancing-front combustion stage.

RATE OF SPREAD

The estimating system that best represents measured rate-of-spread values in grass fuel was calculated from the Rothermel rate-of-spread equation using typical grass fuel characteristics (Rothermel 1972). Calculated values have been converted to tabular form so that the only variables needed to determine the rate of spread are fine fuel moisture and windspeed (table VI-F-4, page 108). Actual fuel moisture can be derived from table VI-F-2 (page 106) where the fuel moisture is shown to be a function of ambient temperature, relative humidity, and cloud cover. The windspeed used should be that at midflame height. This value can be approximated by obtaining the value reported from a 20-foot tower at the nearest fire-danger rating station and dividing that value by 4.

Data from table VI-F-4 (page 108) should be used only for sites with slopes of 20 percent or less. The table is suitable for the Coastal Plains of the South where most prescription burning is done.

Fire travel in feet per minute from the table can be converted to miles per hour as follows:

$$\text{mph} = \frac{\text{feet per minute}}{88}$$

PINE NEEDLE LITTER AND LIGHT BRUSH FUEL TYPES

The forest floor of pine stands having light brush understories may appear quite different from that of a pine stand without an understory, but knowledge gained from studying fuel buildup and fire behavior in these stands shows them to be very similar. They will, therefore, be treated as a single fuel complex.

DESCRIPTION

Pine Needle Litter

In well-stocked pine stands, understory grasses and shrubs are drastically reduced after crowns close due to overhead shading from the pine canopy, competition from pine roots, and the blanketing effect of the shedding pine needles. The areas are generally parklike with a blanket of pine needles covering the soil surface. Understory shrubs that are present are sparsely scattered, and grass is found mainly in stand openings.

This type usually develops where previously cultivated land has reverted to pine forest, and where sites have been carefully prepared by plowing, disking, or bedding prior to pine regeneration.

Light Brush

This type is found throughout the Piedmont and Upper Coastal Plain regions of the Southern States. The fuel mixture consists of grasses, forbs, pine needle litter (usually loblolly pine), deciduous shrubs, and small deciduous trees such as blackgum (*Nyssa sylvatica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), red maple (*Acer rubrum* L.), oaks (*Quercus* spp.), etc. There may also be some scattered nondeciduous shrubs, such as wax myrtle (*Myrica cerifera* L.) or holly (*Ilex opaca* Ait.).

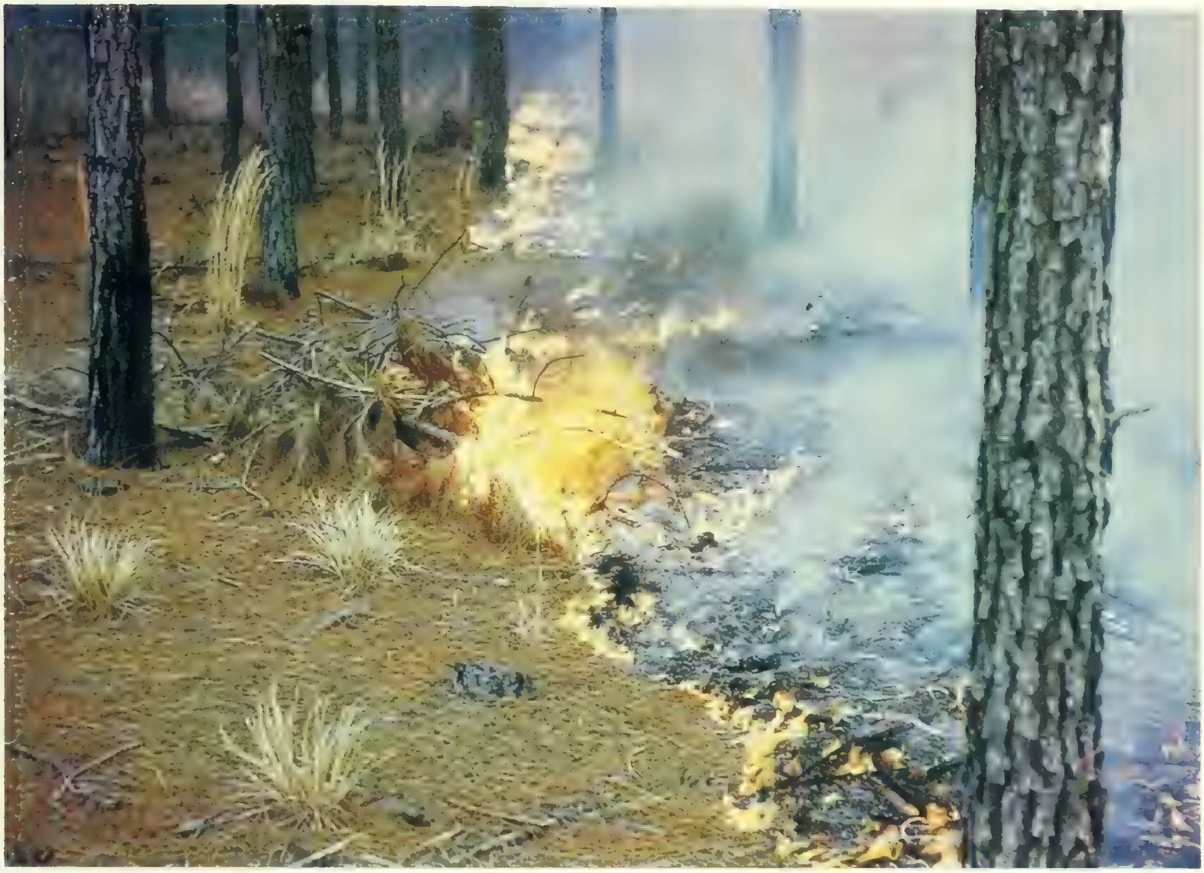

Figure 15. — Backing fire in pine needle litter fuel type.

During the winter and early spring when prescription burning is usually done, only the naked stems of the shrubs are standing. All the leaves have fallen and become part of the litter layer—together with the grass, forbs, and pine needles. Most of the available fuel is in this layer.

FUEL LOADING

Because rate of pine needle accumulation under slash pine stands differs considerably from accumulations under loblolly or loblolly-longleaf stands, separate tables for predicting fuel loading will be presented for each.

Litter accumulation is the same whether an understory does or does not exist. In stands where no understory exists, only the litter fuel need be considered as total fuel for the area. Where understory fuels will be consumed by a prescribed burn, the two fuel fractions must be summed to estimate total fuel.

Slash Pine Litter Total Fuel Estimate

Equations describing the relationships between litter accumulation on the forest floor, basal area, and age of rough have been reported by McNab and Edwards (1976). For field use, the ovendry values are presented in table VI-F-5 (page 109). This table shows, for example, that in a 5-year-old rough where the stand basal area is 70 square feet, there would be a *total* litter accumulation of 6.1 tons.

Slash Pine Litter Available Fuel Estimate

The portion of total fuel that is *available* for consumption by a prescribed fire is directly correlated with the moisture content of the fuel. By estimating *total* loading from table VI-F-5 (page 109) and deriving the total litter layer moisture content (percent), the amount of fuel *available* for burning can be read from the center of table VI-F-7 (page 111). To use the table you must know the total litter layer moisture content, discussed under VARIABLES AFFECTING EMISSIONS AND FIRE PHASES.

Loblolly Pine Litter And Light Brush Total Fuel Estimate

The primary fuel consumed during a prescribed burn in this fuel type is loblolly pine needles, or a mixture of loblolly and longleaf or loblolly and shortleaf needles—possibly with some hardwood brush leaves.

High densities of young hardwood and brush stems are present in this type. During the growing season, the brush is very evident due to the presence of their green leaves; but during dormancy, when all the leaves have been shed, only naked stems are evident. Although they are usually killed by the heat, the stems are not generally consumed in prescribed burns.

An insufficient number of loblolly pine plots were sampled to develop a *total* litter prediction equation as was done with slash pine litter. The slash pine litter model was tried for estimating loblolly litter accumulations using the loblolly stand parameters of basal area and age of rough. In every case, the slash pine model overestimated the actual loblolly weights. We decided to use the model and calculate an error factor by regression:

$$\text{Error factor} = 1 + \left[\frac{3.74 + 4.49\ (\text{age of rough})}{100}\right]$$

Then,

$$\text{Loblolly litter weight} = \frac{\text{Slash pine litter weight}}{\text{Error factor}}$$

Using values from slash pine litter data and the error factor equation, loblolly pine litter accumulations were computed and listed in table VI-F-6 (page 110). Considerable estimation error may occur when using values in excess of 5 tons per acre because those values are extrapolated well beyond the weights actually measured on our limited sample plots.

Loblolly Pine Litter and Light Brush Available Fuel Estimates

Loblolly litter can now be determined from table VI-F-7 (page 111) using the total weight values derived from table VI-F-6 (page 110) and total litter layer moisture content as earlier discussed under VARIABLES AFFECTING EMISSIONS AND FIRE PHASES.

EMISSION FACTOR FOR SLASH AND LOBLOLLY PINE LITTER AND LIGHT BRUSH FUEL TYPES

Particulate matter emissions from burning pine needle litter were derived from laboratory and field experiments by Southern Forest Fire Laboratory personnel.

Backing Fires

As fuel moisture increases, so does emission of particulate matter. Backing fires in laboratory-burned loblolly needle beds at a moisture content of 6 to 10 percent had an emission factor of 17 pounds per ton of fuel consumed; but at a 19 percent moisture content, the value was 28 pounds.

Particulate matter emissions measured on several backing fires in slash pine plantations averaged approximately 50 pounds per ton of consumed fuel. This higher emission factor is thought to be due to differences in moisture content of different litter layers.

Until further knowledge is gained to reconcile the differences in particulate matter emissions between laboratory and field burns, and to account for the effect of fuel moisture, an emission factor of 50 pounds of particulate matter per ton of needles consumed should be used. Most emissions are from the slow-moving flaming portion of the fire.

Heading Fires

Emissions from heading fires moving through pine needle fuel (ER_{A+R}) usually come from both the advancing-front combustion stage and the residual combustion stage that take place immediately after passage of the advancing front. Thus, $ER_{A+R} = ER_A + ER_R$.

In the advancing-front stage the emission factor would be identical to that of backing fires, 50 pounds per ton of fuel consumed; but the emission factor in the residual combustion stage could be up to 180 pounds. These data are based on the burning of small fuel beds in a laboratory, but are the best available.

Where litter buildup is low, as in a 1- to 2-year-old rough, emissions from residual combustion are negligible and only advancing-front combustion need be considered. Such burns would have an emission factor of 50.

RATE OF SPREAD

Pine needle and low-brush fuel types are similar in fuel makeup and arrangement. Fire behavior will, therefore, be considered the same for identical fuel moisture and wind conditions.

The best estimate of rate of fire spread in this fuel type was calculated with the Rothermel spread model (Rothermel 1972). Rates of fire spread are shown in table VI-F-8 (page 112).

As in the grass model, rate of fire spread can be predicted by knowing only midflame windspeed and fine fuel moisture (1-hour timelag) values. This windspeed can be estimated by obtaining a value from a 20-foot, open-tower installation at a nearby fire-danger rating station and dividing that value by 4. Fine fuel moisture can be read from table VI-F-3 (page 107) as a function of only relative humidity. Rate of spread in feet per minute is read from table VI-F-8 (page 112). If desired, the rate of spread in feet per minute can be converted to miles per hour:

$$\text{mph} = \frac{\text{feet per minute}}{88}$$

PALMETTO-GALLBERRY WITH PINE OVERSTORY FUEL TYPE

DESCRIPTION

The vegetation commonly referred to by southern forest fire control personnel as the palmetto-gallberry fuel type can vary widely in amount of vegetation and plant composition throughout its range. Saw-palmetto (*Serenoa repens* [Bartr.] Small) is native to the Lower Coastal Plain, extending south from Charleston, South Carolina, into the whole of Florida and west into southeastern Louisiana (Hilmon 1968).

The gallberry (*Ilex glabra* [L.] Gray) range overlaps the palmetto range, but is considerably more extensive, stretching from Nova Scotia to Louisiana (Gleason 1968). Within the fuel type both shrub species are generally associated and predominate, although in south Florida the gallberry may be totally absent.

Other shrub associates include blueberry (*Vaccinium myrsinites* Lam.), dwarf pawpaw (*Asimina parviflora* [Michx.] Dunal.), titi (*Cyrilla racemiflora* L.), dwarf candleberry (*Myrica cerifera* var. *pumila* Michx.), tar-flower (*Befaria racemosa* Vent.), running oak (*Quercus pumila* Walter.), huckleberry (*Gaylussacia* spp.), fetterbush (*Lyonia lucida* [Lam.] K. Koch), pepperbush (*Clethra acuminata* var. *tomentosa* [Lam.] Michx.), etc.

The herbaceous stratum is made up primarily of grasses and dominated by wiregrass and broomsedge.

The genera *Aristida, Andropogon, Panicum,* and *Rhynchospora* comprise a major portion of the herbaceous weight on sites that are frequently burned. In parts of South Carolina, brackenfern

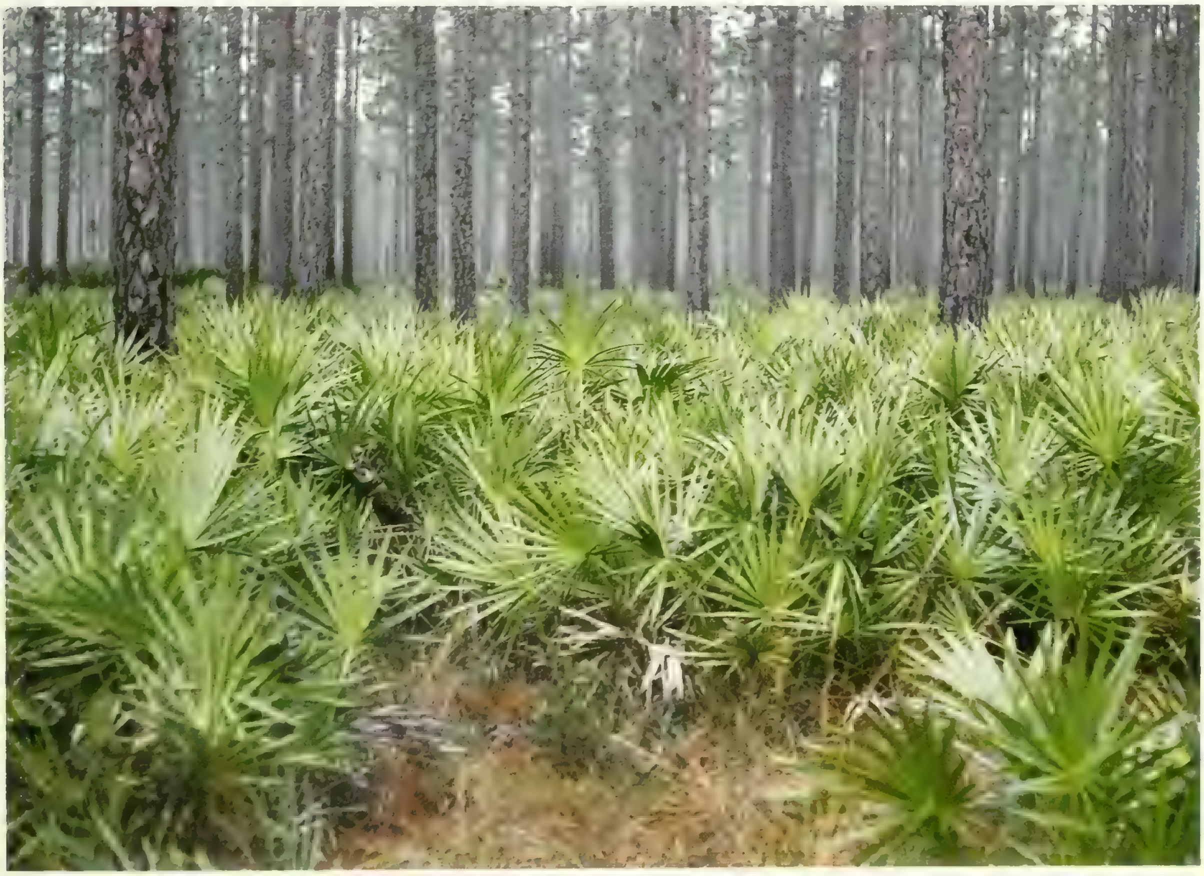

Figure 16. — Palmetto-gallberry fuel type.

(*Pteridium aquilinum* [L.] Kuhn.) is the predominant herb, while tropical shrubs predominate in the south Florida Everglades.

This fuel type is usually found under an overstory of loblolly, slash, or longleaf pine, and considerable quantities of pine needles are mixed with dead grass and other vegetative debris in the ground litter. All estimates of fuel buildup for this type assume the presence of a pine overstory.

FUEL LOADING

The palmetto-gallberry type has two levels of fuel: (1) the understory living vegetation and standing or logged debris and (2) dead material on the forest floor. Separate computations must be made for each level.

Understory

Weight of understory vegetation is related to time since last disturbance (age of rough) and vegetative height. Table VI-F-9 (page 113) shows weights of understory vegetation; but to use it, average height of representative understory vegetation must first be estimated. If, for example, understory height averages 4 feet and age of rough is 3 years, the weight of understory material would be 4.6 tons per acre.

Available Litter Fuel Estimate

The litter buildup in a palmetto-gallberry fuel type is primarily influenced by the pine overstory and should be predicted from table VI-F-5 (page 109) or VI-F-6 (page 110) using basal area of the stand and age of rough as inputs.

Data from prescription-burned experimental plots containing aerial fuel in addition to pine litter were analyzed for fuel consumption. Differences between backing and low-intensity heading fires were not great, so all the data were combined. Data needed to estimate available fuel are:

1. Total standing understory vegetation (table VI-F-9, page 113)
2. Total litter fuel (table VI-F-5, page 109) or VI-F-6 (page 110)
3. Moisture content of the total litter layer from a worksheet (table 9) as shown in this Chapter.

Tables 7 and 8 are used to determine the changes in moisture content of the total litter from normal drying, or from wetting by rain. Their use is explained on pages 31 and 32.

The amount of available fuel consumed from the entire understory fuel bed (includes litter) is presented in table VI-F-10 (page 114). This table has six sections (10, 20, 40, 80, 120, and 160 percent) that represent the range of litter fuel moisture that would be expected when prescribed burning would be considered. The moisture interval is smaller at the lower moisture contents because the change in available fuel consumed is greatest at these lower moisture contents. Should the predicted moisture level not correspond to one of the moisture content sections listed (e.g., 50 percent instead of 40 or 80 percent), choose the section with the closest value (the 40-percent moisture content in this case). Limitations on the accuracy of estimates in the palmetto-gallberry fuel type depend primarily upon the accuracy of the litter and moisture content estimates. These estimates should, therefore, be made with care.

EMISSION FACTOR

The calculated emission factors from experimental field burns in Georgia ranged from 11.8 (pounds of particulate matter per ton of consumed fuel) to 41.2. Based on these field experiments, an advancing-front particulate matter emission factor (EF_A) of 25 pounds per ton of palmetto-gallberry fuel burned is suggested for use with backing fires. This value is believed to be less than emissions from pine needle litter because fuel bulk density is lower and combustion is, therefore, more efficient. No measurements were made for heading fires in the type; if heading fires in 1- or 2-year-old roughs are contemplated, the same emission factor of 25 should be used. Emissions from the residual combustion stage are considered negligible for heading fires in young roughs.

Heading fires in older roughs would evolve appreciable emissions during residual combustion in the litter layer; a much higher emission factor for this stage of combustion (EF_R) of 125 pounds of particulate matter per ton of palmetto-gallberry fuel consumed is suggested for use. The emission rate (ER_{A+R}) for the convective-lift fire phase of older rough heading fires is:

$$ER_{A+R} = ER_A + ER_R$$

RATE OF SPREAD

Rate of fire spread in palmetto-gallberry fuel was estimated from measures of fuel and fire behavior in this fuel type. Hough and Albini (1976) describe the measurement and analytical procedures used to derive the rate-of-spread equations. If windspeed at midflame height and fine fuel moisture (table VI-F-3, page 107) are known, fire spread rate can be read directly from table VI-F-11, page 115. For backing fires, assume the windspeed is zero.

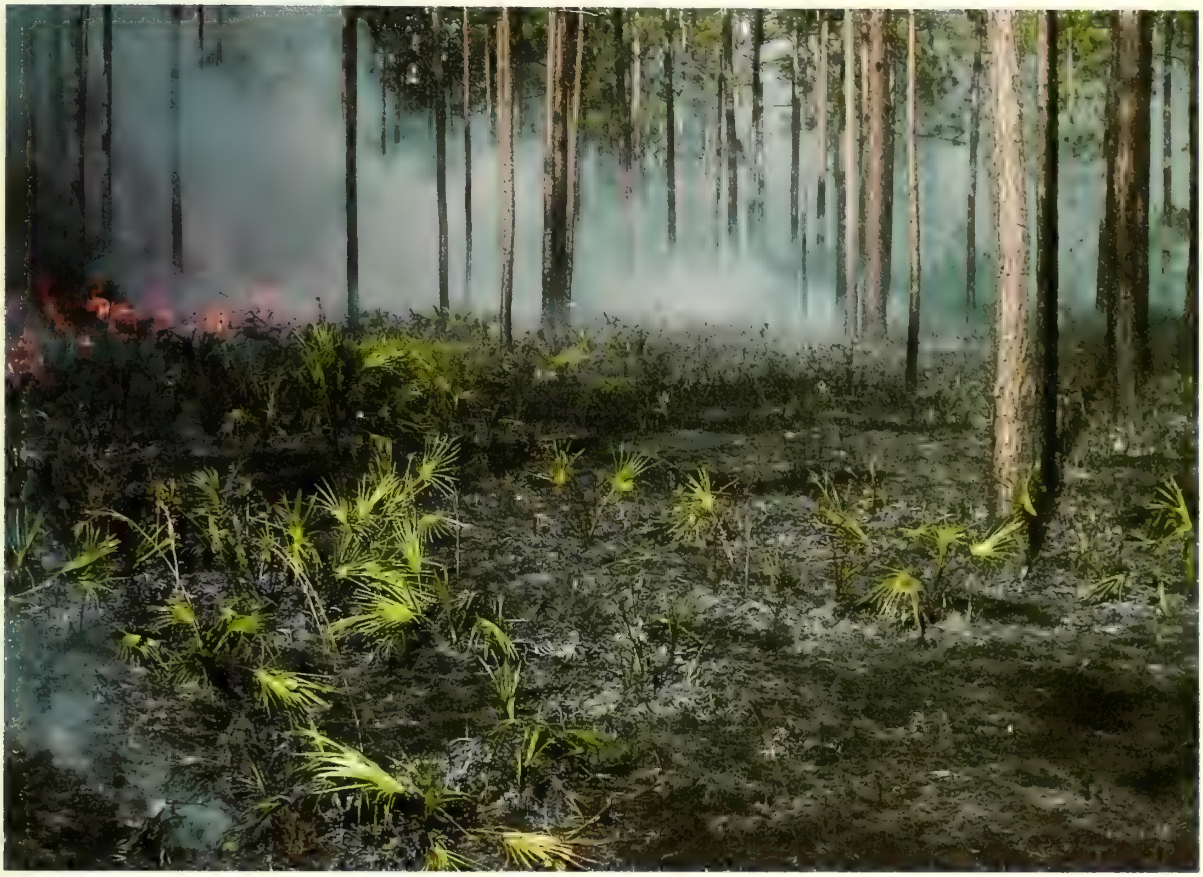

Figure 17. — Emissions from the residual combustion phase in backing fires, and in heading fires with rough less than 2 years old, are negligible for the palmetto-gallberry fuel type.

The proper value to be used for midflame windspeed in table VI-F-11 (page 115) can be estimated by using values taken from a 20-foot, open-tower installation at the nearest fire-danger station and dividing that value by 4. If desired, the rate of spread can be converted to miles per hour:

$$\text{mph} = \frac{\text{feet per minute}}{88}$$

PINE LOGGING DEBRIS FUEL TYPE

DESCRIPTION

This fuel type is made up of tree parts left on an area following logging, plus a very disturbed natural understory fuel. The debris consists mostly of the upper portion of the central bole, tree branches, and needles. Other residue could include unmerchantable "whip" trees and hardwoods.

Logging debris can be burned in one of two ways. The debris can be piled to permit consumption of all small and much of the larger residue elements (branches and tops exceeding 1 inch in diameter), or it can be left scattered where the individual trees were felled to be consumed by a broadcast burn of the area. The latter type burn usually consumes only residue less than 1 inch in diameter.

We have insufficient data to account for differences in emissions from piled debris because piling methods and pile conditions can vary widely. Therefore, this Guidebook will *not* have a section for piled debris. Further research in this fuel type is in progress. The Guidebook does, however, give a procedure for predicting particulate matter emission rate and heat yield from the burning of broadcast debris. This procedure is based upon very scant observations and little experimental evidence.

FUEL LOADING

Residue weight may be estimated by several methods. The traditional procedure is to gather all material from many small sample plots, separate by size class, dry, and express weight on a unit area

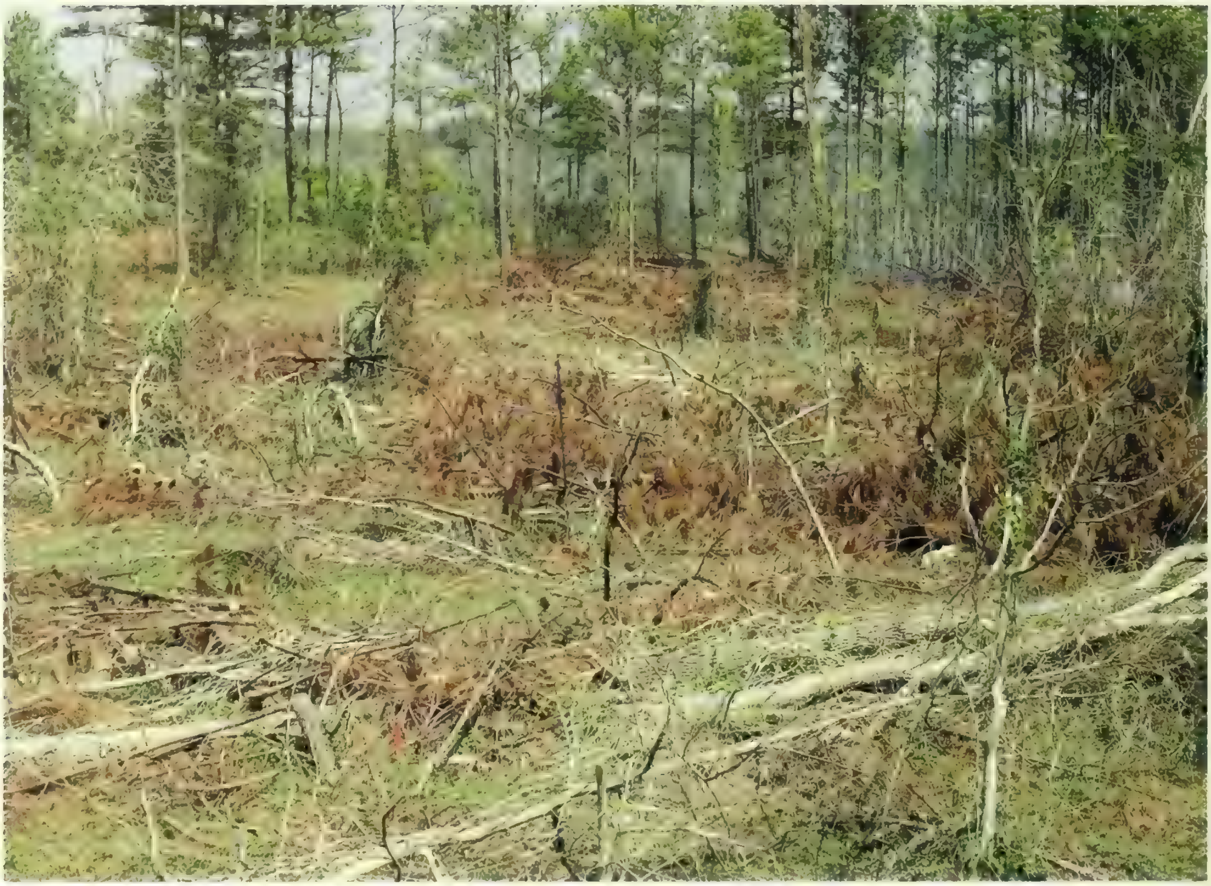

Figure 18. — Unpiled pine logging debris fuel type.

basis. More recent estimating procedures are the line intercept method (Van Wagner 1968) and the planar intercept method (Brown 1971). These methods are useful where the slash from several species of trees is present. The techniques do not require the collection of material, but considerable field time and effort are still needed.

A quicker and more economical method is to relate the quantity of crown residue left on the ground to average diameter at breast height (d.b.h.), basal area, and volume in the stand that was cut. Two studies have been completed on amount of dry residue left on the forest floor following standard logging of two major southern species. One involves loblolly pine residue (Taras and Clark 1974) and the other slash pine residue (data on file at the Southern Forest Fire Laboratory).

Logging debris that has been left undisturbed and is scattered over the entire logged area is generally burned with some form of heading fire. Such fires consume only fuel less than 1 inch in diameter. Table VI-F-12 (page 116) depicts the amount of residue, in tons per cord cut (logged), that would generally be consumed when broadcast burning a logged area. Note that the average d.b.h. of the logged stand has some effect on the amount of residue that will be left on the ground. If d.b.h. of the stand averaged 8 inches and the species was loblolly, for every cord of timber cut there is 0.15 ton of available residue on the ground. If average stand d.b.h. was 11 inches, there is 0.12 ton of available residue per cord. Total residue on an area is the product of tons of residue per cord cut (from table VI-F-12, page 116) and total cords cut on the area. By dividing this answer by the number of acres in the logged area, the residue weight is expressed in tons per acre.

SPECIAL RULE OF THUMB

Debris that has been left broadcast over a logged area is usually burned in one of two ways. It may be head fired from its upwind side toward the downwind side, which is usually backfired in advance. Primary fuel consumption is from the movement of the heading fire, and length of the active burning front for computing heat release rate (HRR) is easily ascertained.

Ring firing may be used instead. This technique usually begins with the firing of the downwind side of the area, followed by the firing of the two flanks simultaneously. Finally, the upwind side is fired to totally encircle the area with fire. Fire movement is toward the center of the area.

Determining the length of active fire for a ring-fired area poses problems. When there is wind movement, the heading portion of the fire is obviously active. But so are the flanks, and as the fire progresses all sides are shrinking in length. For purposes of this Guidebook, the movement of the backing fire will be ignored, even though this side of the fire is obviously contributing some heat and particulate matter to the reaction. Where ring firing is used and there is no wind, all fired sides probably move toward the center at an equal rate.

A rule of thumb has been developed for estimating a length-of-fired line value for computing HRR in Chapter VI. The procedure was developed in an attempt to make an allowance for the fire activity on the burning flanks. To complete the procedure, a scale map of the area to be burned is needed. On the map, draw a line perpendicular to the expected or planned wind direction along the upwind edge of the area to the extremities (fig. 19, line a to b). Draw a second line (c to d) along the downwind edge of the area and connect these two lines with diagonals from the extremities of each. Where the diagonals intersect, label the point (x). Length of fired line for computation of HRR is the sum of scaled lines a to x and b to x. This is the entry needed for Chapter VI.

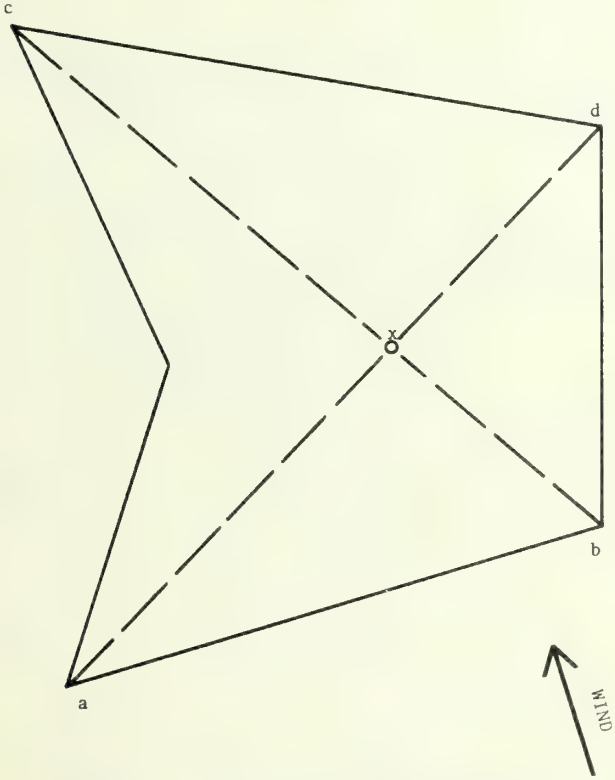

Figure 19. — Procedure for determining length of fired line for heat release rate (HRR) calculations for ring fires in the logging debris fuel type.

EMISSION FACTOR

Emissions from fires moving through unpiled logging debris occur in two phases—the convective-lift phase and the no-convective-lift phase. Emissions during the convective-lift phase are from both the advancing-front combustion stage and the residual combustion stage behind the advancing front.

Six to 18 months usually elapse between logging and burning. During this time much of the accumulated litter breaks down, leaving primarily the logged litter layer of residue over the soil. Upon firing, 75 percent ($y_A = 0.75$) of the available fuel is estimated to be consumed in the advancing-front combustion stage, leaving only 25 percent ($y_R = 0.25$) to be consumed during the residual combustion stage. These proportions are based on data taken from sample areas of debris burned in the southern Piedmont of Georgia near Macon.

Determination of representative emission factors for this fuel type must be partially subjective due to the limited data currently available. Results from the limited fuel beds burned in the laboratory indicate emission factors much below values expected, compared with values for the seemingly similar pine needle litter and palmetto-gallberry fuel types. The difference between expected results and laboratory results can be explained only by hypotheses that: (1) aerial distribution of pine logging debris may result in flame interactions that reduce particulate matter emissions, and (2) laboratory fuel beds used may not have been representative of area-wide fuel arrangements found in actual field situations for pine logging debris.

Laboratory-derived particulate matter EF values of 5 and 75 pounds per ton of fuel for pine logging debris in the advancing-front and residual combustion stages, respectively, must be regarded as tentative until further laboratory and field work is completed. We are suggesting, therefore, that 35 and 180 pounds per ton of fuel be used for the advancing-front and residual combustion stages, respectively. These more conservative EF values for unpiled pine logging debris are drawn from comparisons with other fuel types, but allow for possible interactions indicated by limited laboratory work to date. Use of these values will minimize the risk of unwanted environmental consequences until research is completed.

When computing the emission rate to be used for the convective-lift fire phase for heading (or ring) fires (ER_{A+R}) in this fuel type, the simultaneous activity of both stages of combustion are accountable. The equation is as follows:

$$ER_{A+R} = ER_A + ER_R$$

RATE OF SPREAD

Observations of fire spread rate in this fuel type are limited. Until better data are available, the rate-of-spread curves in NFDRS Model C (Deeming and others 1972) fuel, with modifications (table VI-F-13, page 117), should be used.

The only input variables needed to read rate of spread from table VI-F-13 (page 117) are fine fuel moisture (from table VI-F-3, page 107) and midflame windspeed. The midflame windspeed should be obtained by taking the value at the nearest fire-danger rating station having an anemometer mounted on a 20-foot tower and dividing that value by 2. A factor of 2 is used rather than 4 because of the effect of removing the overstory. If desired, rate of spread can be converted to miles per hour:

$$\text{mph} = \frac{\text{feet per minute}}{88}$$

CONCLUSIONS

Although many voids in knowledge exist, we have presented useful new information on rates of spread and available fuel. These data have been badly needed in the fuel types covered.

In general, practices and fuel conditions that minimize particulate matter production from the burning of forest fuel are:

1. Favoring backing fires where possible
2. Cutting to low stumps and felling dead snags
3. Burning when fuel moisture is low
4. Minimizing amount of logging debris through utilization to small top diameters
5. Burning scattered logging debris rather than piled debris.

LITERATURE CITED

Brown, James K.

1971. A planar intersect method for sampling fuel volume and surface area. For Sci. 17(1):96-102.

Brown, Arthur A., and Kenneth P. Davis

1973. Combustion of forest fuels, p. 163. *In* Forest fire: control and use. 2d ed. McGraw-Hill Book Co., Inc., New York.

Deeming, John E., James W. Lancaster, Michael A. Fosberg, and others

1972. National fire-danger rating system. USDA For. Serv. Res. Pap. RM-84, 165 p. Rocky Mt. For. & Range Exp. Stn., Fort Collins, Colo.

Gleason, Henry A.

1968. Illustrated flora of the northeastern United States and adjacent Canada. 2d ed., vol. 2, 655 p. Hafner Publ. Co.. Inc.,New York.

Grelen, H. E.

1962. Succession on cleared sandhills in northwest Florida. Am. Midl. Nat. 67:36-44.

Helvey, J.D.

1964. Rainfall interception by hardwood forest litter in the southern Appalachians. USDA For. Serv. Res. Pap. SE-8, 8 p. Southeast. For. Exp. Stn., Asheville, N.C.

Hilmon, J. B.

1968. Autecology of saw palmetto (*Serenoa repens* [Bartr.] Small). Ph.D. dissertation, 190 p. Dep. Botany, Duke Univ., Durham, N.C.

Hough, W. A.

1968. Fuel consumption and fire behavior of hazard reduction burns. USDA For. Serv. Res. Pap. SE-36, 7 p. Southeast. For. Exp. Stn., Asheville, N.C.

Hough, Walter A.

In press. Estimating available fuel weight consumed by prescribed fires in the South. USDA For. Serv. Res. Pap. Southeast. For. Exp. Stn., Asheville, N.C.

Hough, Walter A., and Frank A. Albini

In press. Predicting fire behavior in palmetto-gallberry fuel complexes. USDA For. Serv. Res. Pap. Southeast. For. Exp. Stn., Asheville, N.C.

McNab, W. Henry, and M. Boyd Edwards, Jr.

1976. Estimating forest fuel buildup. For. Farmer 35(5):6-7.

Metz, Louis J.

1958. Moisture held in pine litter. J. For. 56(1):36.

Rothermel, Richard C.

1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Res. Pap. INT-115, 40 p. Intermountain For. & Range Exp. Stn., Ogden, Utah.

Swank, Wayne T., Norbert B. Goebel, and Junior D. Helvey

1972. Interception loss in loblolly pine stands of the South Carolina piedmont. J. Soil Water Conserv. 27:160-164.

Taras, Michael A., and Alexander Clark III

1974. Aboveground biomass of loblolly pine in a natural, unevenaged sawtimber stand in central Alabama. TAPPI For. Biol. Conf:107-116.

Van Wagner, C. E.

1968. The line intersect method of forest fuel sampling. For. Sci. 14(1):20-26.

Van Wagner, C. E.

1970. An index to estimate the current moisture content of the forest floor. Dep. Fisheries For., Can. For. Serv. Publ. No. 1288, 23 p., Ottawa, Ontario.

CHAPTER V

SMOKE TRANSPORT AND DISPERSION

by

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The purposes of this Chapter are:

To outline phenomena affecting transport and dispersion of smoke

To introduce concepts of air pollution climatology important to scheduling burning operations when the probability of good smoke transport and dispersion is greatest

To explain the bases we used to select and adapt mathematical models for predicting concentrations of smoke from forestry burning.

The models described were adapted only for common forestry burning situations in the South, but with further adaptation they can be applied elsewhere.

PHENOMENA AFFECTING SMOKE TRANSPORT AND DISPERSION

It has been difficult to achieve a proper balance between too much and too little information for the wide spectrum of readers expected to use this Guidebook. For those who desire more background on basic weather variables, we suggest a text like *Fire Weather* (Schroeder and Buck 1970).

ATMOSPHERIC STABILITY

The definition of atmospheric stability as it affects smoke dispersion is the degree to which the atmosphere resists turbulence and vertical motion. In this discussion it is convenient to consider portions of air as parcels. Parcels of air do not have strict boundaries (as if encased in a wrapper); they tend to mix and take on the characteristics of their surrounding environment.

Consider a parcel of air heated to a certain temperature at the Earth's surface. The more unstable the atmosphere, the more readily the less dense, heated air parcel will rise by convection. Similarly, a more dense, cooled parcel of air will descend more rapidly under unstable conditions. When a parcel of air is heated by a forest fire and carries smoke with it, the rate and height of its ascent are essential to our calculations of subsequent dispersion.

Atmospheric stability is more properly defined by air temperature changes with height over a specific location. The adiabatic lapse rate, a temperature decrease of 1° C per 100 meters (5.5° F per 1,000 feet), defines a neutral atmosphere and is the basic reference for other stability classifications. The atmosphere is unstable if its lapse rate is greater than neutral, and stable if less. Neutral conditions can usually be found below cloud bases during cloudy and windy conditions. An unstable atmosphere usually occurs in early afternoon on clear days with light winds. Stable conditions usually occur at night when the air is clear and the winds are light.

TEMPERATURE INVERSIONS

An inversion layer is a special case of the temperature-height relationship just discussed. Temperature in this layer increases instead of decreases with height. When our previously considered heated parcel of air encounters an inversion layer it soon stops rising. Because it cools quickly as it rises, the parcel reaches the same temperature as the very stable surrounding air. An inversion can thus be thought of as a *lid* on a smoke column.

Forestry smoke managers should be careful to avoid low and intermediate level inversions in order to keep from having such a lid imposed upon the smoke from their burns. If the inversion layer

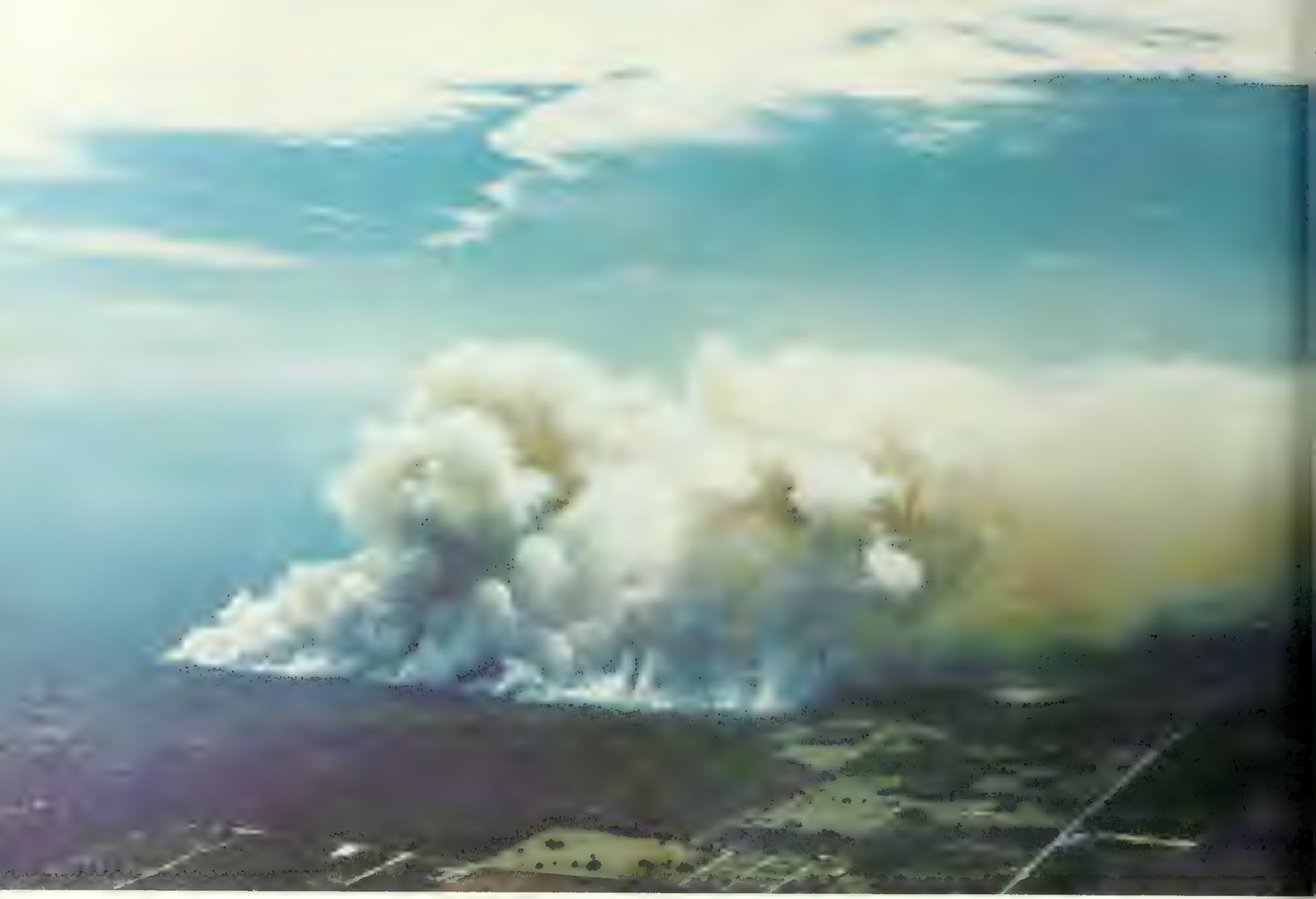

Figure 20. — Major factors affecting smoke transport and dispersion include vertical plume rise, horizontal movement on an azimuth determined by the transport wind direction, and dispersion by physical forces such as atmospheric mixing.

is very weak (i.e., not very thick in the vertical dimension and temperature increase with height is not great), the heated air from a fire can sometimes penetrate this layer. When it does, the smoke then has a better chance for dispersion, but there is often a surprising change in fire behavior. Smoke from the no-convective-lift fire phase will not penetrate the inversion lid. It is, therefore, best to avoid prescribed burning when low inversion layers affecting the fire are predicted.

MIXING HEIGHT

The temperature inversion is one kind of lid that traps smoke beneath it. Stable layers of less than inversion intensity are another form of lid. These lids determine mixing height. Mixing height is the atmospheric limit above which vigorous vertical mixing does not take place. It is a height at which airmass stability is sufficient in strength and depth to inhibit further upward transport of smoke.

Mixing height represents the top of the atmospheric volume available for dispersion. High mixing heights imply that large volumes of air are available for smoke dispersion. Thus, with higher mixing heights, smoke concentrations will be less—especially at long distances from the fire. Mixing heights of less than 500 meters are often associated with air pollution episodes.

TRANSPORT WINDSPEED

You have probably seen smoke columns that go up to one of the lids just described and then just smear out in all directions. This occurs when there is little or no transport wind. The smoke column that bends or shears is encountering wind as it rises.

Windspeeds usually increase with height, except where funneling takes place near the ground (as through a mountain saddle or opening in the forest). Transport windspeed is the arithmetic average of all windspeeds within the mixing layer, including surface windspeed. Smoke concentrations usually decrease as transport windspeeds increase. Transport windspeeds of less than 4 meters per second are indicators of stagnant conditions which often result in air pollution episodes.

TRANSPORT WIND DIRECTION

Wind direction usually veers (changes to the right) with height. Veering with height is important in determining where the smoke will go. The

change in wind direction with height is due to friction that causes ground-level winds to be deflected to the left in the Northern Hemisphere. As the height above the Earth increases, there is a decrease in friction. The rougher the surface, the greater the change. Veering with height over even-aged pine stands on relatively level terrain is between 15 and 20 degrees in the first kilometer (3,281 feet) of height. Over markedly uneven-aged pine stands in rough terrain, it is as much as 40 to 45 degrees. Changes in wind direction with height tend to be more pronounced at night than during the day because vertical motion is usually diminished at night.

LOCAL-SCALE SYSTEMS

Local-scale (sometimes called small-scale) systems are associated with fixed geographic features and do not travel from one location to another like high- and low-pressure systems. They often develop, persist, and dissipate in one small locale. Land and sea breezes are examples of this phenomenon. These breezes change stability, windspeed, and wind direction.

Along coastlines on clear, summer days when early morning winds are light, onshore winds frequently develop by midafternoon—penetrating inland. This sea breeze effect is due to land surfaces being warmer than the sea surface. Similar circulations, much weaker and less widespread, often occur along margins of lesser water bodies, and even open fields, that differ significantly in temperature from adjoining land surfaces.

Mountain-valley or slope-valley wind is another example of a local weather phenomenon that can affect smoke transport and dispersion. On clear nights, high slopes cool by radiation; the air adjacent to them becomes colder and denser, and drains into the valley. The reverse of this drainage flow may occur during the day.

These local-scale systems are important because they directly affect the dispersion of smoke by causing abrupt changes in local atmospheric stability and can influence the direction in which smoke will be transported. They are somewhat predictable—often site dependent.

OBTAINING CURRENT AND FORECAST WEATHER FOR APPLICATION

Limits on values for the phenomena covered in the preceding section need to be specified in a fire prescription, then checked against current and forecast weather for a specific locale, and for specific times.

National Weather Service Forecast Offices can supply the following information in spot forecasts:

Mixing height (also referred to as height of the mixing layer)

Surface windspeed (in the open at a height of 10 meters)

Transport windspeed

Transport wind direction.

Both transport windspeeds and mixing heights are reported in metric units. The probable transport wind velocity (direction and speed) is usually the vector-sum of reported or forecast winds through the mixing height.

As of this writing, stability expressed in the Pasquill (1975) stability classes used in Chapter VI is not available through the National Weather Service. These values may eventually be provided, but until they are the smoke manager must predict the class from reported *cloud cover* and *cloud height* plus angle of the sun. A predicting method is provided in Table 11.

POLLUTION CLIMATOLOGY

Forestry smoke managers responsible for a large number of planned burns are urged in Chapter VI to develop schedules based upon the total number of days with good probability of satisfactory smoke transport and dispersion, as well as other burn objectives. To do this requires an understanding of the climatology of pollution and a knowledge of available sources of appropriate climatologies. This leads us to consider again the phenomena affecting transport and dispersion discussed earlier.

Climate, the synthesis of these conditions over a long time, should be used in formulating long-range prescribed burning plans. Climatic conditions to be considered in prescription burning plans include stagnation, mixing, windspeed, and wind direction frequencies.

To avoid high concentrations of smoke in sensitive areas, burning often has to be done when the

Table 11. — Stability estimating method [1]

Surface windspeed (mph)	DAY									NIGHT	
	Clear or 50% or less cloud cover w/ low & mid clouds; or any high clouds			More than 50% low and mid clouds			More than 50% low clouds			50% or more cloud cover w/low and mid clouds or high overcast	Clear or less than 50% cloud cover w/ low and middle clouds
	6-foot vertical standard shadow length (in feet)										
	Less than 3.5	3.5 to 8.5	Greater than 8.5	Less than 3.5	3.5 to 8.5	Greater than 8.5	Less than 3.5	3.5 to 8.5	Greater than 8.5		
Less than 4	A [3]	A-B	B	A-B	B	D	B	D	D	DO NOT BURN [2]	DO NOT BURN [2]
4 - 7	A-B	B	C	B	C	D	C	D	D	E	F
8 - 10	B	B-C	C	B-C	C	D	C	D	D	D	E
11 - 14	C	C-D	D	C-D	D	D	D	D	D	D	D
More than 14	C	D	D	D	D	D	D	D	D	D	D

[1] After Pasquill (1975), with insolation estimates incorporating shadow length or cloud cover after Lavdas (1976).

[2] Burns will be delayed in Decision-Logic Stage No. 1, Chapter VI.

[3] Shaded areas indicate categories for which typical cases are not presented in Chapter VI.

How to use table:

1. Locate main column head for day or night. Night applies from 1 hour before sunset to 1 hour after sunrise.
2. Locate subcolumn head for cloud cover.
3. If for day situation, locate sub-subcolumn head for 6-foot vertical standard shadow length.
4. Locate row for surface windspeed.
5. In row and under column, read stability class category.

Example: Day with more than 50 percent low and mid clouds and shadow length less than 3.5 feet with windspeed 8 to 10 mph. Read stability category B-C.

wind is blowing in a particular direction. Forestry smoke managers can determine the probability that the wind will be blowing in the proper direction on a given day from summaries of prevailing seasonal wind directions.

Needed climatological information may be found in the literature cited in this section. The Climatic Atlas of the United States (available from the National Climatic Center, Federal Building, Asheville, North Carolina 28801) is another comprehensive source. This publication gives monthly and seasonal averages and totals for most of the phenomena affecting transport and dispersion. Airport summaries of windspeed and direction frequencies are available from the National Climatic Center as well.

Two primary factors that inhibit atmospheric dispersion are light winds and stable atmospheres. When these persist, stagnation occurs. High-pressure systems, or anticyclones, exhibit both of these characteristics. Korshover (1971) used 35 years of upper air observations to determine the relative occurrence of stagnant anticyclones. He found that stagnant conditions in the Southeast occur most frequently during late summer and fall. The maximum number of stagnant episodes lasting 4 days or more occurred in north Georgia and in western North and South Carolina.

Stagnant anticyclones are not the only systems that result in poor dispersion conditions. Dilution capacity of the atmosphere may be poor during other meteorological patterns, such as when inversions persist. Hosler (1961) reported the frequency of low-level (less than 500 feet) inversions over the Continental United States during a 2-year period. His findings agree well with Korshover's (1971)—inversions causing poor dispersion patterns in the Southeastern United States occur most frequently in the fall, but may occur in any season.

Holzworth (1972), in his analysis of 5 years of National Weather Service data, presented mixing heights, windspeeds, and the resulting potential for urban air pollution throughout the contiguous United States. His generalizations may be applied to rural atmospheres.

MATHEMATICAL MODELS

Different assumptions about governing processes and behavior have resulted in many different models for calculating dispersion. Some are different merely because of their intended application. Additional work will undoubtedly yield yet a wider variety from which to choose. In the discussions that follow, we will address the criteria we used for selecting a dispersion model—as well as the related approaches used in the decision logic in Chapter VI. We will also cover modifications imposed upon selected approaches, but will leave full development and defense of previously published equations to cited sources.

Three general criteria were applied in selecting and adapting the model:

1. Predictions close to the burn are the most critical, and the model must accurately reflect source and atmospheric variables.

2. The model must be widely accepted by scientists in regulatory agencies.

3. The model must permit either computer or desk-top calculations.

In order to provide a practical predictive method for smoke concentrations at downwind locations, it has been necessary to assign fixed values for some factors. In Chapter IV two separate fire phases are described: the *convective-lift* and the *no-convective-lift fire phases.* While smoke entrainment will gradually increase then decline in the convective-lift phase, use of a steady state is believed to be realistic in order to make calculations manageable. In the no-convective-lift phase, emissions will gradually decline; but again, using a steady-state condition is necessary if anything but extremely complex equations calling for automatic data processing are to be applied. Similar steady-state compromises are applied in the final transport and dispersion model to be introduced in this section for use in Chapter VI. In addition to these practical considerations, current knowledge does not justify more sensitive, time-dependent adjustments at this time.

PLUME RISE

The height that the center of the smoke plume attains is called plume rise. During the convective-lift phase of combustion, heat released by the fire causes convective lift of emissions from the fire in a definite column. As this heat diminishes, the plume loses its columnar shape to a point where lift of emissions is mostly a result of vertical atmospheric mixing alone. Thus, while atmospheric stability is an important variable at all times, heat release rate, explained in Chapter IV, will be employed only for the convective-lift phase. Winds impinging upon the column during the convective-lift phase tend to bend or shear it, restricting the total possible plume rise. Plume rise, therefore, is a function of heat release rate, atmospheric stability, and transport windspeed. Inversions will also limit plume rise and are accounted for by stability. Mixing height becomes important after the initial convective lift, and is incorporated in the final dispersion model.

In discussions with Dr. Gary A. Briggs of the NOAA Oak Ridge Laboratory, we elected to adapt the plume rise relations he developed for stack emissions handled as point sources. Briggs' (1969, 1971, 1972) plume rise relationships fit satisfactorily for prescribed fires when his term Q_H is expressed as the total rate of heat release from the entire length of fired line, as determined by relationships explained in Chapter IV. Relationships were examined for stability classes A through F (Pasquill 1975). Equations (1) through (4) are used in calculating ultimate plume height, in which:

H = height (in meters)

Q_H = total heat release (in calories per second)

u = transport windspeed (in meters per second).

For stability classes A through D, and Q_H less than 1.40×10^6 cal/sec:

$$H = 0.0101\, Q_H^{3/4}\, u^{-1} \qquad (1)$$

For stability classes A through D, and Q_H greater than 1.40×10^6 cal/sec:

$$H = 0.0847\, Q_H^{3/5}\, u^{-1} \qquad (2)$$

For stability class E and all values of Q_H (temperature increase with height of 1°C per 100 m assumed):

$$H = 0.917\, Q_H^{1/3}\, u^{-1/3} \qquad (3)$$

For stability class F and all values of Q_H (temperature increase with height of 2.5°C per 100m assumed):

$$H = 0.761\, Q_H^{1/3}\, u^{-1/3} \qquad (4)$$

Equations (1) through (4) are used to calculate plume rise while the smoke rises for some distance as it travels downwind. Often ultimate height is not reached for several kilometers downwind. This distance is not affected by transport windspeed. Briggs' (1969) ultimate height for a 1 megacalorie per second source is attained about 480 meters (0.3 mile) downwind. From Briggs' work, downwind distances to ultimate heights for sources releasing heat at different rates under stability classes A through D compare as follows:

Heat release (Megacal/sec)	**Approximate downwind distances to ultimate heights (Miles)**
1	0.3
10	0.8
100	2.0

It can be shown that at one-third the downwind distance to ultimate height, one-half the ultimate height is consistently attained. For example, a 10 megacalorie per second fire with an ultimate plume rise limited to 250 meters will have attained a height of 125 meters at 0.27 mile downwind (i.e., 1/3 x 0.8 mile).

When Briggs' (1969) equation (4.30) is applied, most southern prescribed fires are shown to be unable to penetrate a modest inversion of 1° C at 100-meter elevations or higher.

Now we have a means to express the total height of the plume. That portion of the smoke observed to remain unentrained and traveling along the ground still remains to be accounted for. This phenomenon is experienced even during the hottest portion of the convective-lift phase in southern prescribed fires. Additional research is needed, but observations of the phenomenon on three experimental fires were used to arrive at a ratio of 60-rise to 40-no-rise for the amount left unentrained. This ratio was borne only by observations on a fourth experimental fire.

The 60:40 ratio has thus been suggested for a limited number of both heading and backing fires. When heat release (HR, the heat released per unit of fired-line length, rather than the total heat release rate (HRR), or Q_H) is increased, the ratio can logically be expected to increase toward 100:0, provided stability and transport windspeed remain unchanged. For example, a campfire can be seen to lift all emissions by convection so long as its heat causes a *draw* from all portions of the fire. But the same fire, while still maintaining a convection column, will in time cease to draw smoke from its outer portions. Smoke from these portions will then tend to drift free from convective lift. This is essentially what takes place in most southern prescribed fires covered in the logic of Chapter VI. It seems likely additional research will lead to adjustments in the 60:40 ratio.

In working with plume rise under unstable atmospheric conditions, the effect of vertical wind eddies that temporarily bring high smoke concentrations aloft closer to the ground have been evaluated. The largest vertical eddies occur when instability is greatest. Eddy sizes decrease as conditions become more nearly stable, and the plume rise fluctuations become less significant. These conditions have been found to be important to dispersion calculations for emissions from cool sources like elevated smoke stacks, but they have not been observed in our experimental fires in the Southeast.

To summarize, two expressions have been introduced. These are the factor H for ultimate plume height, and the coefficient 0.6 for the amount of smoke entrained in the convection column of the convective-lift fire phase. Both will be noted as adaptations in the dispersion model to be discussed in following subsections.

SELECTION OF A DISPERSION MODEL

Forest managers have been exposed to the "tank concept" and to applications of a "box model" of dispersion. These names are sometimes incorrectly described as interchangeable. Before selecting any more complex model, it was thus necessary to assess possible adaptations of these two relatively simple approaches.

The "tank concept" is a convenient way of thinking about a certain atmosphere's ability to "absorb" a specified level of air pollutants. The atmosphere, of whatever dimension, is thought of as a container with imaginary "walls" (such as mountains, but sometimes only arbitrary or political boundaries) and a "lid" (such as imposed by an inversion or by the mixing height). It is assumed that smoke is distributed evenly, and that emissions can be accommodated until smoke concentrations reach an accepted maximum for the "tank" as a whole. Unfortunately for a management use of this concept, however convenient it may be in gaining an initial grasp of air pollution problems, the real world of smoke transport and dispersion does not operate nearly so simply! Within the "tank," emissions from each source flow along an axis determined by the transport wind direction. Initial horizontal and vertical diffusion (dispersion) is defined by physical laws that do not result in uniform distributions of pollutant concentrations, even when the "tank" has real walls such as a valley or mountain canyon. The result is that along the path of the plume initial smoke concentrations will be greater than in the "tank" as a whole (a very undemocratic consequence for individuals along the plume's path if they are depending upon administrators of the "tank" to assure them their equal share of pure air).

The term "box model" differs from the "tank concept" in that dispersion takes place along an axis determined by transport wind direction. Distribution, however, is considered to be uniform. This model has gained acceptance through application to dispersion problems in the Willamette Valley of Oregon (Reiquam 1970). A derivation labeled the "smoke-volume model" has been suggested by Williams (1974) for application to prescribed fires. This variant differs from the box model in that the plume is restricted by formulas based upon measured heights and widths of experimental fires. The principal advantage of uniform distribution models is the ease with which calculations for different downwind distances can be accomplished. A potential for solution of long-range transport problems has been identified (Pasquill 1972). The chief disadvantage, however, is that because plume rise is not accounted for, the predicted ground-level concentrations due to a uniform vertical distribution are not valid for locations within the first 100 kilometers (62 miles) of sources.

Wide acceptance has been gained for application of the Gaussian distribution to dispersion modeling. A statistical tool, the Gaussian distribution permits a general description of smoke plume dispersion over time. There have been numerous independent validations in both laboratory and field experiments (Hay and Pasquill 1957; Cramer, Record, and Vaughan 1958; and Barad and Haugen 1959). A workbook, published by the U.S. Environmental Protection Agency (Turner 1970), enjoys widespread application by scientists working on dispersion. This approach employs Gaussian distribution, as well as a synthesis of the work of other accepted authorities. Methods of the Turner Workbook (1970) have thus been selected for use in this Guidebook.

ADAPTATION OF THE TURNER WORKBOOK METHODS TO A MODEL FOR MANAGING SMOKE FROM PRESCRIBED FIRE IN THE SOUTH

Our initial adaptation of the Turner Workbook is straightforward, with Equation (5) being the model used. Combinations of terms and derivations are after Turner (1970), except as adaptations are explained in the list of variables and coefficients (table 12).

$$\chi = \frac{q}{\sqrt{2\pi}\, u\sigma_z} \left\{ 1.6 \sum_{N=1}^{N=3} \exp\left[-0.5\left(\frac{H}{\sigma_z}\right)^2\right] + 1.2 \exp\left[-0.5\left(\frac{H}{\sigma_z}\right)^2\right] + \right.$$

$$\left. 1.2 \sum_{N=1}^{N=3} \left(\exp\left[-0.5\left(\frac{H - 2NM}{\sigma_z}\right)^2\right] + \exp\left[-0.5\left(\frac{H + 2NM}{\sigma_z}\right)^2\right]\right)\right\}$$

$$\int_{-L/2\sigma_y}^{L/2\sigma_y} \frac{1}{\sqrt{2\pi}} \exp\left[-0.5\ (y/\sigma_y)^2\right] d(y/\sigma_y) \qquad (5)$$

Table 12.—Variables and adaptive coefficients used in Equation (5). Other coefficients are from Turner (1970).

Variable or coefficient	Definition and discussion	Units
χ	Centerline, ground-level concentration	micrograms/meter^3
H	Plume rise, adapted from Briggs (1969, 1971, 1972) and as recommended by Turner (see Plume Rise discussion)	meters
L	Length of fired-line adaptation	meters
M	Mixing height, the height in the atmosphere to which turbulent mixing occurs	meters
N	Reflection numbers (as smoke bounces off the ground or stable layers) after Bierly and Hewson (1962)	nondimensional
q	Emission rate per unit length of fired-line adaptation (equivalent to ER)	micrograms/meter-second
u	Transport windspeed	meters/second
y	Variable crosswind distance from midpoint of fireline to the limits $\pm$ L/2σ_y	meters
σ_y	Horizontal standard deviation of plume concentration distribution	meters
σ_z	Vertical standard deviation of plume concentration distribution	meters
1.2 and 1.6	Adapted coefficients resulting from combination of terms with the 0.6 coefficient for the 60-percent entrained and 40-percent unentrained smoke covered under Plume Rise.	nondimensional

Besides being a complex series of terms, Equation (5) calls for certain inputs which are difficult to derive. Some simplifications can be achieved by solving for the relative concentration, $\frac{\chi u}{q}$ on the left-hand side. Transport windspeed, u, and mixing height, M, are readily obtainable for field application, but the remaining three variables on the right—horizontal and vertical standard deviation of plume concentration distribution, σ_y and σ_z, and plume rise, H, all call for more than the equation itself.

This need for further adaptation brought us to three alternatives:

1. Using a computer program to generate a series of graphs or look-up tables
2. Offering a computer program in a form that could be accessed by users
3. Providing a combination of look-up tables and typical cases with predicted concentrations that could be adjusted to actual cases.

The first of these alternatives resulted in such an unwieldy set of tables, graphs, instructions, and intermediate calculations that it was discarded. Alternative No. 2 is in progress at this writing. Recognizing the value of close exposure to the actual procedures, and recognizing as well that some users would not have immediate access to automatic data processing, we have pursued alternative No. 3 in this Guidebook.

PLOTTING RESULTS OF CALCULATIONS

When ground-level dispersion patterns calculated with a modified Gaussian distribution model are plotted to scale, they will typically show curves like those of figure 21.

Because of possible deviations of the actual wind direction from the forecast, and the need to avoid underestimating smoke impact at designated targets, the Gaussian model is not used in unmodified form for predicting downwind smoke

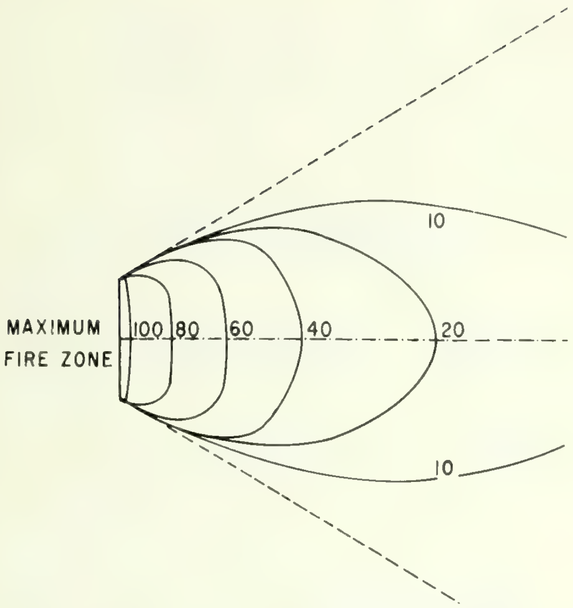

Figure 21. — Ground-level dispersion patterns from a modified Gaussian distribution model. Concentrations are shown on a hypothetical scale of 100 for ease of visualizing changes.

concentrations. Rather, a system that extends the centerline concentrations 30° to either side of the expected downwind direction is used. A possible promise of partially reducing this admittedly conservative allowance, as well as others, lies in automatic data processing for predicting trajectories and concentrations on the day of burning. This promise lies in an ability to work with more massive data from localized weather forecasts which are adjusted over time as the smoke plume travels downwind. While the technology is available now, a conservative procedure must be suggested for use until adaptive work in progress can be completed.

The presently suggested procedure calls for plotting the crosswind length of the line to be fired and plotting a downwind trajectory from the center point of that line. From the ends of the line, downwind trajectories are plotted as dashed lines for a distance of twice the crosswind length of the fired line. From these end trajectories, lines of the limits of possible smoke impact are drawn at 30° outward angles. The trapezoid-like figure that results depicts the area of probable smoke impact.

Concentrations in the impact area are determined by striking arcs through the centerline trajectory at specified distances. At distances less than twice the crosswind line length, two arcs should be struck using the line end points as centers. The two end point arcs are then connected by a straight line passing through the trajectory centerline. Beyond two fired-line lengths downwind, this procedure may be satisfactorily approximated by simply drawing a single arc between the smoke impact limits with the middle of the crosswind line as the center for the arc. The resulting plot, like the one shown in figure 22, differs from figure 21 by intention. This difference allows for a plot of predicted maximum concentrations by zones that extend through the centerline to either edge of the trajectory, thereby avoiding underestimates of concentration due to transient or unexpected wind or centerline shifts.

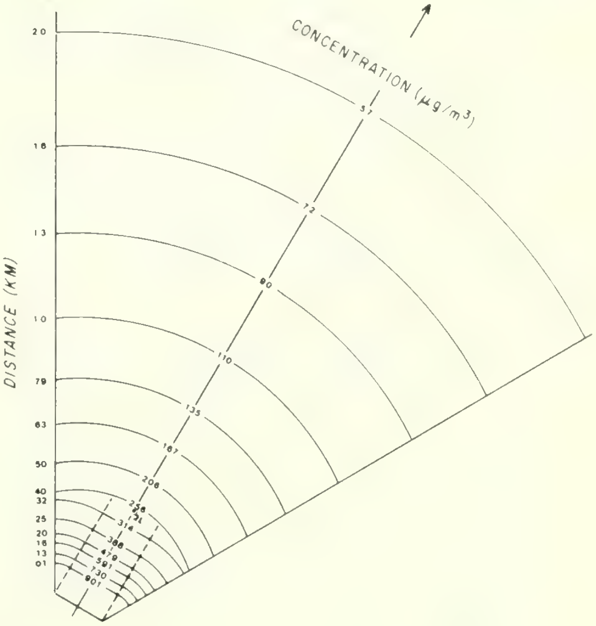

Figure 22. — Plot of predicted centerline concentrations like those to be employed in Chapter VI. The "2L" point indicates twice the fired-line length.

When completed, these plots are used to obtain a total predicted concentration at any potential downwind target by adding the concentration within the zone defined by an arc to the "background" pollutant concentration at the potential target. This permits rapid comparison of total predicted concentrations with acceptable concentrations for all potential targets.

A rule of thumb (Noll and others 1968) can be employed to estimate "background" pollutant concentrations when these have not been quantified by other means. The rule is limited to relative humidities of 70 percent or less and to particulate matter 0.3 micron in diameter and larger. To use the rule, 730 micrograms per cubic meter per mile are divided by the visibility in miles. For example, if the visibility is 5 miles, the "background" pollutant concentration is estimated to be:

$$\frac{730\,\mu g/m^3/mi}{5\,mi} = 146\,\mu g/m^3$$

LONG-RANGE TRANSPORT

Transport of emissions beyond the 100 km (62 miles) limit of the model employed becomes a new predictive problem. Because this problem is almost in a province of regional smoke management, we have made no attempt to provide any adaptation from among the best of several models under study at this time. We have, however, recognized the importance of the normally stable trend toward evening. At the same time, we have attempted to provide a margin of safety to help assure the manager that smoke from a single burn will not contribute to problems beyond 100 km. To do this, we devised a procedure called *Long-Range Transport Margin* which is incorporated in Chapter VI.

BASIS FOR LONG-RANGE TRANSPORT MARGIN

For fires in fuel types known to be relatively heavy emitters, when the convective-lift fire phase will extend beyond 3 hours before sunset, users will find themselves referred to figure VI-M-1 in Chapter VI. To use figure VI-M-1, a graphic intersection of the fire emission rate (ER) and transport windspeed is located. If the intersection is either to the left of, or upon, the sloping internal line

$$\frac{qL}{u} = 7.5 \times 10^8 \text{ micrograms/m}^2\text{-sec}, \qquad (6)$$

the burn may be considered *safe*. If the intersection is to the right of the line, the fire prescription should be modified.

The principal consideration underlying this procedure is to avoid carrying concentrations of particulate matter in excess of 150 micrograms per cubic meter beyond 100 km when stable conditions can be expected.

The following assumptions have been made in constructing figure VI-M-1:

1. D stability
2. No plume rise (because at 100 or more km a plume is well mixed within the mixing layer)
3. Point source (source configuration is of no consequence at 100 km)
4. Relative concentration, $\frac{\chi u}{qL}$, at 100 km is 2×10^{-7} meter^{-2}, which is consistent with 150 micrograms/m^3; variables are the same as previously listed.

LIMITATIONS OF THE MATHEMATICAL MODEL

Of the essential model, Turner (1970) points out that it "... may provide *best estimates* but not infallible predictions." We offer the adapted model in this same frame of reference. In addition to other limitations mentioned in preceding discussions, it is particularly important to note that as the smoke disperses with time, stability and other weather variables will change. The present model does not account for these changes. We have, however, covered one procedure adapted from the model to provide a margin of safety for long-range transport. This procedure is made part of those in Chapter VI to partially compensate for changes in stability. Finally, the user of the procedures in Chapter VI must recognize limitations in the accuracy of weather forecasts. In making these *best estimates* the user is allowing for upward and downward mixing within a zone of concentration. As a consequence, not all potential targets will be receptors at any given instant. He is portraying the potential concentration at each target.

LITERATURE CITED

Barad, M. L., and D. A. Haugen

1959. A preliminary evaluation of Sutton's hypothesis for diffusion from a continuous point source. J. Meteorol. 16(1):12-20.

Bierly, E. W., and E. W. Hewson

1962. Some restrictive meteorological conditions to be considered in the design of stacks. J. Appl. Meteorol. 1(3):383-390.

Briggs, G. A.

1969. Plume rise. Air Resour. Atmos. Turbul. and Diffus. Lab., Environ. Sci. Serv. Adm., U.S. Atomic Energy Comm., 81 p., Oak Ridge, Tenn.

Briggs, Gary A.

1971. Some recent analyses of plume rise observations. *In* Proc. Sec. Int. Clean Air Congr., p. 1029-1032, Acad. Press, New York.

Briggs, Gary A.

1972. Discussion, chimney plumes in neutral and stable surroundings. Atmos. Environ. 6(7):507-510.

Cramer, H. E., F. A. Record, and H. C. Vaughan

1958. The study of the diffusion of gases for aerosols in the lower atmosphere. Final Rep., Contract AF19(604)-1058, 70 p., Mass. Inst. of Tech., Dep. Meteorol., Cambridge, Mass.

Hay, J. S., and F. Pasquill

1957. Diffusion from a fixed source at a height of a few hundred feet in the atmosphere. J. Fluid Mech. 2, Part 2, p. 299-310.

Holzworth, George C.

1972. Mixing heights, windspeeds, and potential for urban air pollution throughout the contiguous United States. U. S. Environ. Prot. Agency, Off. Air Programs, Publ. No. AP-101, 118 p., Research Triangle Park, N.C.

Hosler, Charles R.

1961. Low-level inversion frequency in the contiguous United States. Mon. Wea. Rev. 89(9):319-339.

Korshover, Julius

1971. Climatology of stagnating anticyclones east of the Rocky Mountains, 1936-1970. NOAA Tech. Memo. ERL-ARL-34, 27 p., U. S. Dep. Commer., Natl. Oceanic & Atmos. Adm., Silver Spring, Md.

Lavdas, Leonidas G.

1976. A groundhog's approach to estimating insolation. J. Air Pollut. Control Assoc. 26(8):794.

Noll, Kenneth E., Peter K. Mueller, and Miles Imada

1968. Visibility and aerosol concentration in urban air. Atmos. Environ. 2(5):465-475.

Pasquill, F.

1972. Factors determining pollution from local sources in industrial and urban areas. The Meteorol. Mag. 101(1194):1-8.

Pasquill, F.

1975. Atmospheric diffusion. 2d ed., p. 368. John Wiley and Sons, New York.

Reiquam, H.

1970. An atmospheric transport and accumulation model for airsheds. Atmos. Environ. 4(3):233-247.

Schroeder, Mark J., and Charles C. Buck

1970. Fire weather ... A guide for application of meteorological information to forest fire control operations. USDA For. Serv. Agric. Handb. 360, 228 p., USDA For. Serv., Washington, D.C.

Turner, D. Bruce

1970. Workbook of atmospheric dispersion estimates. U. S. Environ. Prot. Agency, Off. Air Programs, Publ. No. AP-26, 84 p., Research Triangle Park, N.C.

Williams, Dansy T.

1974. A smoke volume model for prescribed fire. *In* Proc. Symp. on Atmos. Diffus. & Air Pollut.: Santa Barbara, Calif., p. 159-162. Publ. by Am. Meteorol. Soc., Boston, Mass.

CHAPTER VI
HOW TO MANAGE SMOKE

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This Chapter is written to help manage smoke from forestry prescription burning once the decision to burn has been made. No attempt is made here to evaluate alternatives to burning. Sometimes, the logic steps may lead to a suggestion that the decisionmaker take a new look at other possible treatments. We will first discuss the concepts of smoke management planning and then present a decision-logic procedure. Part 3 of this Chapter contains tables needed to follow some of the more complex logic.

PART 1. PLANNING FOR SMOKE MANAGEMENT

A written burning plan should be prepared in advance for each area to be burned. It should contain a scheduling system and prescription elements that aim at both accomplishment of objectives and avoidance of unwanted air quality effects. We suggest that, as used, the worksheets presented in Part 2 of this Chapter be attached to file copies of completed plans.

SCHEDULING

The number of days during a season with conditions fitting both resource management objectives and air quality objectives is limited. As a consequence, it is likely that the number of large burns will increase on the few days when both sets of constraints are met. Smoke from several forestry sources could tax the smoke-absorbing capacity of target-area atmospheres on these days. A need for systematic and careful scheduling of burns is called for.

A scheduling system that minimizes the effects on air quality should include the following elements:

An analysis of the number of days each year when weather is likely to meet both management objectives *and* air quality objectives

The numbers, sizes, and locations of desired burns listed by priority and difficulty of burn—along with likely-best smoke plume trajectories

A method of allocating available days to desired burns

A procedure for selecting alternate burn tracts when unfavorable weather conditions prevent following the schedule

An inventory of expected *background* particulate matter concentrations in areas likely to be downwind from prescribed burning operations.

PLANNING CHECKLIST

1. Follow a formally prepared plan.
2. Be sure all legal requirements are met.
3. Provide in advance for burning permit, receipt of weather forecasts, and prior measurement of variables like total litter layer moisture content.
4. When windrowing and piling debris, provide for best drying and avoid mixing with dirt.
5. Follow a decision logic to determine the kind of day on which you should be able to burn with good smoke management.

6. Use localized weather information, asking for spot fire-weather forecasts and updates.

7. Burn when wind will not carry smoke into sensitive areas (targets).

8. Seek unstable weather conditions, but not extremes.

9. Avoid days with low morning transport windspeed (less than 4 mph).

10. Avoid days with low morning mixing heights (less than 500 meters).

11. Seek dry fuel conditions, but not extremes.

12. Seek low relative humidity, but not extremes.

13. Be cautious of nighttime burning (if permitted).

14. Be especially cautious when burning a large area or a heavy loading of fuel.

15. Use firing technique that produces the least emissions.

16. Be prepared to mop up stumps and snags, especially if large and decaying.

17. Make last-minute check on weather conditions.

18. Remember that fires have to be controlled, and timber should not be excessively scorched; as dispersal conditions improve, fire intensity increases.

19. Be alert for a change in weather conditions.

PRESCRIPTION ELEMENTS

Combinations of the following fire prescription elements are necessary to plan for maintenance of air quality. Some variables that are foreign to foresters will be needed for smoke management. In the list of elements which follows, numbers in parentheses refer to the decision-logic stages where each is used:

Fuel type (No. 1 and No. 2)
Age of rough (No. 1 and No. 2)
Total litter layer moisture content (No. 2)
Fine fuel moisture (No. 2)
Firing pattern (No. 2)
Length of fired line (No. 1 through No. 3)
Relative humidity (No. 2)
Air temperature (No. 2)
Stability (No. 1 and No. 3)
Mixing height (No. 1)
Surface windspeed and direction (No. 1 and No. 2)
Transport windspeed and direction (No. 1, No.3, and No. 5).

PART 2. DECISION LOGIC

INTENDED USE AND LIMITATIONS

You are now well aware of the large amount of information that must be integrated to determine if fire prescriptions will meet air quality objectives. To accomplish this task, we have developed a decision-logic system for applying the best knowledge available. The system applies the mathematical models and concepts discussed in Chapters IV and V. The criteria for the system are discussed in Chapter III under A VOLUNTARY DECISION PROCEDURE PROPOSED FOR FORESTRY SMOKE MANAGEMENT, starting on page 26.

The system calls for the user to specify his own fire prescription elements and to adopt acceptable levels of total suspended particulate matter (TSP) for target areas downwind. While designed for advance planning, the system should also be used on the day of burning with actual and forecast values substituted for prescribed values.

Our intent is to provide the easiest possible procedure to *AVOID OVERLOADING NATURAL CLEARANCE MECHANISMS*. A model is a representation of beliefs about a natural system, not necessarily what actually takes place. For manageability, models used for dispersion calculations and for heat release rate (HRR) and emission rate (ER) calculations are dependent only upon values expected as averages for *steady-state* conditions during two discreet fire phases. We have chosen this course rather than attempt to impose more realistic, but exceedingly complex, equations—allowing for changes in state during the life of the burn. For these reasons, the logic system's predictions may be incorrect at times even though the system applies the best available technology.

OVERVIEW

The system is divided into six stages to keep the user oriented as he progresses. It is designed for desk-top calculations. As presented here, system responses to variability have been compressed to facilitate use. For example, in one instance, many separate operations and at least 32 tables are represented by only a few typical cases.

Stage No. 1 is for relatively simple screening of prescriptions. From it the user can decide to burn, not to burn, or to proceed with more detailed analyses in subsequent Stages. We expect that this first Stage will cover many prescription burns. Stages No. 2 through No. 5 apply to more complex situations where decisions are not immediately obvious. Stage No. 6 introduces automatic data processing options.[5]

Stage No. 2 is the logic for determining fuel and fire characteristics so that emission rate and heat release rate can be calculated. Stage No. 3 provides for determining a margin of safety for concentrations carried long distances. In Stage No. 4, the user matches his prescription variables to typical burning cases. Provision is made to correct for differences between presented and typical cases. Then, downwind concentrations of total suspended particulate matter can be calculated. In Stage No. 5, comparisons are made between predicted and user-specified total suspended particulate matter concentrations at targets. Decisions to be reached at this point are: to follow the burn prescription, to revise the prescription further, to find an alternative to burning, or to proceed with an analysis that requires automatic data processing.

We recognize that small landowners will find Stages No. 2 through No. 5 especially bothersome without technical staff or assistance. An adaptation of Stage No. 1 has been published for their use in uncomplicated situations (Tangren 1976).

In more complex situations, there are no easy ways to determine smoke dispersion without automatic data processing.

For those who do not have access to a computer, the desk-top decision-logic procedure will seem tedious. We believe it is the only way, however, to assure proper analyses, and we advocate its initial use even for those who have access to automatic data processing.

USE OF WORKSHEETS

Each Stage of the logic is presented in worksheet format. It is suggested that you make copies of these worksheets (yellow pages). Save one set of copies for future use as an original, then use extra copies as working papers to include with each burn plan and prescription.

---

[5] Programs will be provided in the Forestry Smoke Management Sourcebook.

DECISION-LOGIC STAGE #1: INITIAL SCREENING

To use this decision logic you should have already prepared a written prescription, and you should be familiar with applicable air quality rules, regulations, and standards. If there are no obvious situations that preclude burning, you are ready to proceed.

This Stage will help you decide if your prescription calls for a burn that is:

possible without modification
possible with modification
not possible.

We believe most prescribed fires will fall into the first two categories.

Steps 1.2 and 1.3 contain questions to be answered YES or NO. If all applicable questions are answered YES, the burning prescription can be followed without modification. Burning is still possible if all NO answers can be changed to YES by modifying the fire prescription; for example, by calling for another time to burn when mixing heights are more favorable, or when the transport wind direction will not carry smoke into target areas. If you answer NO and cannot modify the prescription to be able to answer YES, you should not burn unless you favorably complete a more detailed analysis in Stages #2 through #5.

1.1 PREPARATION

1.1a Wind Direction and Targets:

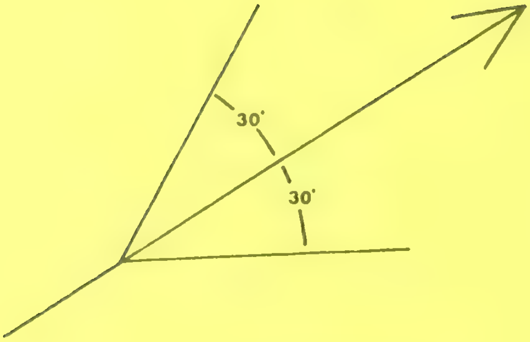
(1) Obtain map(s) covering improvements detail for 60 miles downwind from burn. Obtain azimuths of paths from burn prescription for both the convective-lift (CL) and the no-convective-lift (NCL) fire phases. Locate burn on map and, using protractor and straight edge, draw lines representing centerline of paths of smoke plume. Use two different colors to plot the two phases. Then check here and proceed.

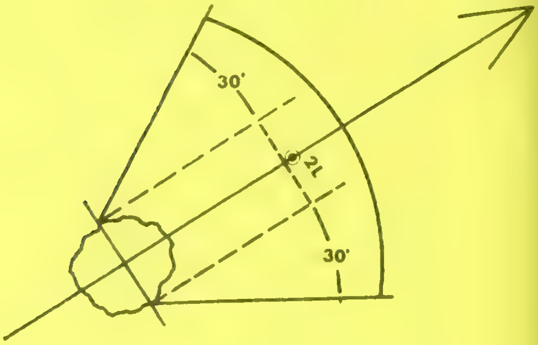
_____

Prescription specifics:

Convective-lift phase transport wind azimuth ________°
No-convective-lift phase transport wind azimuth ________°
(NCL is omitted for backing fires)

(2) Now you must allow for the width of the fire and shifts of the smoke plume centerline. Plot as in figure A if the fire is represented by a small dot. If it is larger, plot as in figure B.





Within the plotted areas, look for any improvements or other potential target (e.g.: town, Air Quality Maintenance Area, highway, village, hospital, factory, residence, airfield, etc.) that you consider critical from an air quality standpoint. Then check here and proceed.

_____

(3) If in rare cases no potential targets are found, this logic need not be applied, and you may burn without further use of the procedure. If any targets are identified, you should continue with the procedure. Attach your map(s) to this Worksheet and check *one* of the following:

Target(s) identified, logic will be applied
(go on to Step 1.b)_____
No target(s) identified, logic need not be
applied further (Stop)_____

1.1b Fuel Type:

(1) At this time, research is not sufficiently complete to cover other than the following fuel types. If your fuel type is other than the ones listed, you must decide if one of these is reasonably comparable to proceed through the rest of the logic *using this type*, or you must plan your prescription without aid of the logic system.

Palmetto-gallberry_____
Grass with pine overstory_____
Pine needle litter_____
Light brush_____
Unpiled pine logging debris_____

(2) Check the appropriate fuel type above if yours matches, or if you select a type as nearly comparable as you can.

(3) If you selected a comparable type, circle the checkmark.

(4) If you checked none of the types listed, you may wish to use this Stage #1 Worksheet, but do so with special caution and *do not attempt to use Stages #2 through #6.*

(5) Now check one of the following:

Type matches or comparable type selected,
and logic will be applied _____
Type does not match, and comparable type
not selected
but Stage #1 will be applied_____
and Stage #1 will not be applied_____

1.2 CRITICAL TRAJECTORIES

If a NO answer is given to any of the following questions, it is most desirable to prescribe a new *transport wind direction* to avoid target areas in question. *Be sure to also rework Step 1.1a to reflect the new prescribed azimuths.*

If you cannot prescribe a new wind direction you should proceed immediately with Stages #2 through #5, but be prepared to encounter downwind concentrations that may not be acceptable.

1.2a Sulfur Dioxide Interactions:

Does your trajectory avoid the chance that critical sources of atmospheric emissions containing SO_2 will merge with the emissions from your burn.[1]

YES _____
NO _____

1.2b Unacceptable Background Level:

Are all identified target areas likely to be free from other known air pollution problems at the time of burn? (Allow for other forestry burning.)

YES _____
NO _____

1.2c Is the area within 3/4 mile of your burn free of targets?

YES _____
NO _____

1.3 MINIMIZING RISK

You should always determine if you can readily change your prescription to obtain a YES answer whenever you have checked NO in this set of questions.

---

[1] Sulfur dioxide, SO_2, is believed by many authorities to become a more likely health hazard in the presence of particulate matter from any source. If local guidance on critical sources is not available to you, a good rule is to avoid all sources.

1.3a Is your fuel type other than logging debris?

YES ____[2]
NO ____

1.3b For all other fuel types if your rough is older than 2 years, is a backing fire prescribed and is total fuel loading less than 10 tons per acre?[3]

YES ____[2]
NO ____

1.3c Will the burn be conducted when background visibility is likely to b at least 5 miles at all points within the first 60 miles along the plotted trajectory? (Step 1.1a)

YES ____
NO ____

1.3d Are all other known or expected sources of emissions (including other prescribed burns) displaced to the side of your plotted trajectory (Step 1.1a) by a distance of at least one-half their downwind distance and are any targets in overlapping area farther than 2 km (1.2 miles)?

YES ____
NO ____

1.3e Does your prescription call for the forecast mixing height to be 500 meters or more?

YES ____
NO ____

1.3f Is the prescribed transport windspeed 4 or more meters per second?

YES ____
NO ____

1.3g If your plan calls for a night burn, have you prescribed a surface windspeed greater than 4 mph and a backing fire?

YES ____
NO ____
NOT APPLICABLE ____

---

[2] Go directly to Stage #2 since prescription cannot be changed.

[3] This question reflects the application of current best available technology in limiting total suspended particulate matter (TSP) regardless of chemical nature.

1.3h If a burning permit is locally required, do your prescription elements match *permit* requirements and does your plan call for obtaining the required permit?

YES _____
NO _____[4]
NOT APPLICABLE _____

NOTE: You now have a set of answers to help you screen your prescription. If you have completed the preparatory Steps in Steps 1.1 and have now answered YES to all questions asked in Steps 1.2 and 1.3, you do not need to go on to Stages #2 through #5. Instead, it is likely your prescription will provide for good smoke management and you are ready to burn. If you have answered NO and cannot revise your prescription, you should not burn until you have favorably completed Stages #2 through #5.[5]

---

[4] Do not proceed to Stage #2 if permit is required and NO has been answered.

[5] CAUTION: Stages #2 through #6 are likely to yield DO NOT BURN decision advice if you are using any of the following:

Less than 500 meters mixing height
Less than 4 mph surface windspeed
Less than 4 meters per second transport windspeed
Background visibility on trajectory less than 5 miles.

SPECIAL INTRODUCTION TO STAGES #2 THROUGH #5

If an automatic data processing procedure for smoke management decisions is available to you, you should skip immediately to Stage #6.

The following interrelated parameters are needed to predict total downwind concentrations that will be used for comparisons with acceptable concentrations. The variables used to derive them are provided.

Parameter	Variables
Total litter layer moisture content	Previous litter layer moisture content, age of rough, yesterday's duration of precipitation (see Chapter IV).
Fuel loading	Fuel type, age of rough, stand basal area, understory height (palmetto only), average d.b.h. (logging residue only), cords cut (logging residue only).
Available fuel	Fuel type, fuel loading, total litter layer moisture content.
Emission factor	Fuel type, combustion stage, age of rough, burning method.
Fire phase	Heat release rate.
Combustion stage	Fire behavior.
Fine fuel moisture	Temperature, relative humidity, sky condition (grass only).
Stand characteristics	Preburn inventory or preharvest inventory.
Rate of spread	Fine fuel moisture, windspeed at midflame height, fuel type.
Length of fired line	Prescription, plot geometry (for ring fires only).
Heat release rate	Available fuel, rate of spread, length of fired line.
Particulate matter emission rate	Available fuel, rate of spread, emission factor.
Mixing height	Observed and forecast weather.
Transport windspeed and direction	Observed and forecast weather.
Stability class	If not forecast by the National Weather Service: solar angle (shadow length), cloud cover and height, 10-meter windspeed (see Chapter V).
Target-area *background* concentrations	Effects of other emissions sources.

This decision logic does not apply to slopes greater than 20 percent.

Two sets of reference figures and tables will be used in working through the logic stages. The first set (tables VI-F-1 through VI-F-13) is related to fuels and fire behavior and is printed on pink paper. The second set (tables VI-M-1 through VI-M-6 and figure VI-M-1) is related to meteorology and is printed on blue paper. Many calculations are represented by these figures and tables. Derivations are explained in Guidebook Chapters IV and V.

In preparing to use the Stages, it is important to recognize two constraints in the system presented:

1. For each fuel type, an average emission factor (EF) has been derived for the most likely fuel conditions. We know that moisture and other variables will affect the EF, but believe the current state of knowledge does not warrant further refinement in calculations at this time.

2. The strategy here is to limit concentrations of total suspended particulate matter (TSP). Future control strategies may include control of specific components of smoke.

DECISION-LOGIC STAGE #2: RATE DETERMINATIONS

You have been directed here from Stage #1 because one of your responses indicated a degree of risk calling for more complex analyses, and/or you were unable to modify your fire prescription.

From the list of parameters in the Special Introduction preceding this Stage, you will have noted a number of new prescription elements. Your prescription will require more detail, and we suggest you prepare the prescription as you work through this and subsequent Stages--adding new variables as needed.

CAUTION: Do not proceed unless your prescription calls for a relative humidity of less than 71 percent during the convective-lift and no-convective-lift phases. (Predictions above this humidity are not to be used and the logic does not apply.)

A. DETERMINATION OF STAGE #2 WORKSHEET SET TO BE USED:

The fuel type you selected in Step 1.1b was (check one, then proceed to next step on indicated Worksheet Set):

Palmetto-gallberry _____	Go directly to Worksheet Set 2B
Grass with pine overstory _____	Go directly to Worksheet Set 2C
Pine needle litter or light brush _____	Go directly to Worksheet Set 2D
Unpiled pine logging debris _____	Go directly to Worksheet Set 2E.

DECISION-LOGIC STAGE #2 APPLIED TO PALMETTO-GALLBERRY FUEL TYPE

You Have Been Directed Here From Worksheet Set 2A

2B.1 FUELS

2B.1a Make the following entries from your inventory of the burn area:

(1) Stand basal area is _____ sq ft/acre
(2) Age of rough is _____ yr
(3) Predominant overstory timber species is (check one):
Slash pine _____
Loblolly pine _____
(4) Average height of understory component is _____ ft

2B.1b With entries (1), (2), and (3) from above, use table VI-F-5 if the predominant species is slash pine, or use table VI-F-6 if the predominant species is loblolly pine, to determine the total litter weight, entering the value here:

_____ ton/acre

2B.1c With entries (2) and (4) from above, use table VI-F-9 to determine the understory vegetative dry weight, entering the value here:

_____ ton/acre

2B.2 TOTAL LITTER LAYER MOISTURE CONTENT

2B.2a Prescribe a maximum total litter layer moisture content (TLLMC). (Review Southern Forestry Smoke Management Guidebook Chapter IV for procedure and requirements.) The TLLMC will be:

_____ %

2B.2b Assure that the burning plan provides for observing and recording actual TLLMC. Then return here, check, and proceed to next step.

_____

2B.3 TOTAL AVAILABLE FUEL

2B.3a With the total litter weight you determined in Step 2B.1b, the understory vegetative dry weight you determined in Step 2B.1c, and the prescribed maximum TLLMC you entered in Step 2B.2a, use table VI-F-10 to determine the estimated total available fuel (litter and vegetation), entering the value here:

_____ ton/acre

2B.4 PINE NEEDLE MOISTURE CONTENT AND BURNING METHOD

2B.4a Make the following entries from your written prescription for subsequent use:

Maximum relative humidity _____%
Minimum windspeed (20-foot tower) _____mph
Burning method (check one):
Heading fire _____
Backing fire _____

2B.4b With the relative humidity entry from above, use table VI-F-3 to determine the pine needle litter moisture content, entering the value here: _____ %

2B.5 WIND EFFECT

2B.5a If you have prescribed a heading fire, divide windspeed you entered in Step 2B.4a by 4 to arrive at an estimated midflame windspeed, entering the value here; if you have prescribed a backing fire, enter a zero here: _____ mph

2B.6 RATE OF SPREAD

2B.6a With the pine needle litter moisture you determined in Step 2B.4b and the windspeed you determined in Step 2B.5a (the windspeed used here for a backing fire is always 0), use table VI-F-11 to determine rate of spread, entering the value here:

_____ ft/min

2B.7 COMBUSTION STAGES

2B.7a Because a sizable fraction of the fuels, when heading fired, will remain to be consumed in the residual combustion stage after the advancing-front combustion stage passes, an adjustment is needed to proportion the amount of fuel available to each stage. A suggested advancing front:residual ratio of fuel consumed is 50:50. When backing fires are employed, almost all of the fuel is consumed during the advancing-front combustion stage, and a ratio of 1:0 is appropriate. Now select the values you judge most appropriate and enter here:

(1) Decimal fraction of fuel consumed in advancing-front stage (y_A) _____
(2) Decimal fraction of fuel consumed in residual stage (y_R); ($1.00 - y_A$) _____

2B.8 EMISSION FACTORS

2B.8a The suggested TSP emission factors (EF) for the palmetto-gallberry type are:

Age of rough and burning method	Emission factors (lbs/ton) Advancing-front stage EF_A	 Residual stage EF_R
≤2 years backing or heading and >2 years backing	25	None
>2 years heading	25	125

Now, opposite your age of rough and burning method, either circle the EF value(s) to be used or enter new values if better data are available to you.

2B.9 EMISSION RATES

2B.9a Perform the indicated multiplications by entering the values from the steps shown in the following equations.

(1) Calculate ER_A, the total suspended particulate matter (TSP) emission rate, for the advancing front combustion stage:

$$ER_A = 570 \times \underset{\text{(Available fuel from Step 2B.3a)}}{\underline{\qquad\qquad}} \times \underset{\text{(Rate of spread from Step 2B.6a)}}{\underline{\qquad\qquad}}$$

$$\times \underset{\text{(Consumption adjustment } (y_A) \text{ from Step 2B.7(1))}}{\underline{\qquad\qquad}} \times \underset{(EF_A \text{ from Step 2B.8a})}{\underline{\qquad\qquad}}$$

ER_A = ________ micrograms TSP/meter-second (μg TSP/m-sec)

(2) If your prescription is for a backing fire in any age rough, or for a heading fire in rough 2 years old or less, skip directly to Step 2B.9b.

If your prescription is for a heading fire in rough more than 2 years old, calculate ER_R, the TSP emission rate for the residual combustion stage:

ER_R = 570 x ____________ x ____________
(Available fuel from Step 2B.3a) (Rate of spread from Step 2B.6a)

x ____________ x ____________
(Consumption adjustment (y_R) from Step 2B.7a(2)) (EF_R from Step 2B.8a)

ER_R = ________ µg TSP/m-sec

(3) Now calculate ER_{A+R}, the TSP emission rate for the convective-lift phase of heading fires in rough older than 2 years:

ER_{A+R} = ____________ + ____________
(ER_A from Step 2B.9a(1)) (ER_R from Step 2B.9a(2))

ER_{A+R} = ________ µg TSP/m-sec

2B.9b If you were told to skip to this Step from Step 2B.9a(2), enter the value of ER_A, from Step 2B.9a(1) in the blank below for ER_{CL}, and NONE in ER_{NCL} below, then skip directly to Step 2B.10.

If you calculated ER_{A+R} in Step 2B.9a(3), enter the value for ER_{A+R} in the blank below for ER_{CL}, then enter the value for ER_R from Step 2B.9a(2) in the blank below for ER_{NCL}.

ER_{CL} = ________ µg TSP/m-sec

ER_{NCL} = ________ µg TSP/m-sec

2B.10 HEAT RELEASE RATE

2B.10a Make the following entry from your written prescription:

Length of fired line _____ ft

2B.10b Using the length of fired line from the Step immediately above and the same weight of available fuel and rate-of-spread values just used in Step 2B.9a, calculate the heat release rate (HRR) for the convective-lift phase of your fire. Heat release has negligible effect for the no-convective-lift phase.

HRR_{CL} = 0.0012 x ____________ x ____________
(Available fuel from Step 2B.3a) (Rate of spread from Step 2B.6a)

x ____________ x ____________
(Consumption adjustment (y_A) from Step 2B.7a(1)) (Length of fired line Step 2B.10a)

HRR_{CL} = ________ megacal/sec

NOW SKIP DIRECTLY TO STAGE #3

DECISION-LOGIC STAGE #2 APPLIED TO GRASS WITH PINE OVERSTORY FUEL TYPE

You Have Been Directed Here From Worksheet 2A

2C.1 FUELS

2C.1a Make the following entries from your inventory of the burn area for subsequent use:

(1) Age of rough _____ yr
(2) Stand basal area _____sq ft/acre
(3) Predominant overstory (check one):

Slash pine _____
Loblolly pine _____

2C.1b With entry (1) from above, use table VI-F-1 to determine the total available grass weight, entering the value here:

_____ton/acre

2C.1c With entries (1), (2), and (3) from above, use table VI-F-5 if the predominant overstory is slash pine, or table VI-F-6 if the predominant overstory is loblolly pine, to determine the total needle litter weight, entering the value here:

_____ ton/acre

2C.1d Compare the entry you made for the grass weight in Step 2C.1b with the entry you made for the needle litter weight in Step 2C.1c. Is the grass component greater?

Yes _____ then proceed to Step 2C.2
No _____ then skip directly to Worksheet 2D and reclassify fuel type as pine needle litter, the more applicable fuel type.

2C.2 WINDSPEED AND RELATED PRESCRIPTION ELEMENTS

2C.2a Make the following entries from your written prescription for subsequent use:

Expected cloud cover (check one): Sunny _____
Cloudy _____
Minimum windspeed (20-foot tower) _____mph
Temperature _____°
Maximum relative humidity _____%
Burning method (check one): Heading fire _____
Backing fire _____

2C.2b If your prescription calls for a backing fire, skip directly to Step 2C.3.

If your prescription calls for a heading fire, divide windspeed you entered above by 4 to arrive at an estimated midflame windspeed, entering the value here:

_____ mph

2C.3 RATE OF SPREAD

2C.3a Use the appropriate prescription entries in Step 2C.2a with table VI-F-2 to determine fine fuel moisture for dead grass, entering the tabular value here:

_____ %

2C.3b If you completed Step 2C.2b, use the midflame windspeed, or for backing fires use a zero windspeed, along with this fine fuel moisture to determine the rate of fire spread for grass from table VI-F-4, entering the tabular value here:

_____ ft/min

2C.4 TOTAL LITTER LAYER MOISTURE CONTENT

2C.4a Prescribe a maximum total litter layer moisture content (TLLMC) (review Southern Forestry Smoke Management Guidebook Chapter IV for procedure and requirements). The maximum TLLMC will be:

_____ %

2C.4b Assure that the burn plan provides for observing and recording actual TLLMC. Then return here, check, and proceed to next step:

_____

2C.5 AVAILABLE LITTER FUEL

2C.5a With the total litter weight (needle fuel) you determined in Step 2C.1c and the prescribed TLLMC you entered in Step 2C.4a, use table VI-F-7 to determine the available fuel in pine needle and associated vegetative litter other than grass, entering this value here:

_____ ton/acre

2C.6 COMBINED TOTAL AVAILABLE FUEL

2C.6a Add the total available grass weight from Step 2C.1b to the available litter fuel from Step 2C.5a, entering the total here:

__.__ ton/acre

2C.7 EMISSION FACTORS AND RATES FOR GRASS

2C.7a An emission factor (EF) of 15 pounds per ton of fuel consumed is suggested for grass fuels from experiments to date. Using this or other information available to you, select an EF appropriate to your prescribed burn, entering the value here:

EF = _____ lb/ton of fuel

2C.7b Using the determined values from the Steps shown in the following equation, calculate an emission rate (ER) by performing the indicated multiplications:

$$ER_A = 570 \times \underset{\text{(Combined total available fuel from Step 2C.6a)}}{\underline{\hspace{6em}}} \times \underset{\text{(Rate of spread from Step 2C.3b)}}{\underline{\hspace{6em}}} \times \underset{\text{(EF from Step 2C.7a)}}{\underline{\hspace{6em}}}$$

ER_A = _____ μg TSP/m-sec

2C.7c Since there is no appreciable residual combustion stage (and thus no no-convective-lift fire phase) for this fuel type with all burning methods, the advancing-front emission rate (ER_A) is equivalent to the convective-lift (CL) fire phase. For this reason, enter the ER_A value you determined in Step 2C.7b in the blank below:

ER_{CL} = _____ μg TSP/m-sec

2C.8 HEAT RELEASE RATE

2C.8a From your written prescription, enter here the length of fired line:

_____ ft

2C.8b Calculate the heat release rate (HRR) for your fire by entering the determined values from the Steps shown in the following equation and performing the indicated multiplications:

HRR_{CL} = 0.0012 x ________________ x ________________
(Combined total available fuel from Step 2C.6a) (Rate of spread from Step 2C.3b)

x ________________
(Length of fired line from Step 2C.8a)

HRR_{CL} = _____ megacal/sec

DECISION-LOGIC STAGE #2 APPLIED TO PINE NEEDLE LITTER AND/OR LIGHT BRUSH

You Have Been Directed Here From Worksheet Set 2A, or by fuel type reclassification from Worksheet Set 2C

2D.1 FUELS

2D.1a (1) If you have been directed here from Worksheet Set 2A, skip directly to Step 2D.1b.

(2) If you have been directed here from Worksheet Set 2C, bring forward your entries from that Worksheet as follows:

Total available grass weight ______________ ton/acre (from Step 2C.1b)

Pine needle total litter weight ______________ ton/acre (from Step 2C.1c)

(3) Now skip directly to Step 2D.2.

2D.1b Make the following entries from your inventory of the burn area for subsequent use:

(1) Stand basal area is _____ sq ft/acre
(2) Age of rough is _____ yr
(3) Predominant overstory is (check one): Slash pine _____
Loblolly pine _____

2D.1c With the entries (1), (2), and (3) from above, use table VI-F-5 if the predominant species is slash pine, or use table VI-F-6 if the predominant species is loblolly pine, to determine the total litter weight, entering the value here:

_____ ton/acre

2D.2 TOTAL LITTER LAYER MOISTURE CONTENT

2D.2a Prescribe a maximum total litter layer moisture content (TLLMC) (review Southern Forestry Smoke Management Guidebook Chapter IV for procedure and requirements). The TLLMC will be:

_____ %

2D.2b Assure that the burn plan provides for observing and recording actual TLLMC. Then return here, check, and proceed to next step:

_____

2D.2c You will now use either the pine needle total litter weight from Step 2D.1a(2), if you completed this Step, or use the total litter weight from Step 2D.1c, if you completed this Step. With the value for total litter weight and the prescribed maximum TLLMC you entered in Step 2D.2a, use table VI-F-7 to determine the available litter fuel, entering the value here:

_____ ton/acre

2D.3 RATE OF SPREAD

2D.3a Make the following entries from your written prescription:

Relative humidity _____ %
Windspeed (20-foot tower) _____ mph
Burning method (check one): Heading fire _____
Backing fire _____

2D.3b With the relative humidity entry from above, use table VI-F-3 to determine the pine needle litter moisture content, entering the value here:

_____ %

2D.3c If you have a prescribed heading fire, divide windspeed you entered in Step 2D.3a by 4 to arrive at an estimated midflame windspeed, entering the value here; or if you have prescribed a backing fire, enter a zero:

_____ mph

2D.3d With the pine needle litter moisture content you determined in Step 2D.3b and the windspeed you determined in Step 2D.3c (the windspeed used here for a backing fire is always 0), use table VI-F-8 to determine rate of spread, entering the value here:

_____ ft/min

2D.4 COMBUSTION STAGES

2D.4a Because a sizable fraction of the fuels, when heading fired, will remain to be consumed in the residual combustion stage after the advancing-front combustion stage passes, an adjustment is needed to proportion the amount of fuel available to each stage. Limited laboratory data suggest the advancing-front:residual ratio of fuel consumed is 50:50. When backing fires are employed, almost all of the fuel is consumed during the advancing-front combustion stage and a ratio of 1:0 is appropriate. Now, select the values you judge most appropriate and enter here:

(1) Decimal fraction of fuel consumed in advancing-front stage (y_A): _____

(2) Decimal fraction of fuel consumed in residual stage (y_R) ($1.00 - Y_A$): _____

2D.5 EMISSION FACTORS

2D.5a The suggested total suspended particulate matter (TSP) emission factors (EF) for the pine needle/light brush fuel type are:

Age of rough and burning method	Emission factors (lbs/ton) Advancing-front stage EF_A	 Residual stage EF_R
≤2 years backing or heading and >2 years backing	50	None
>2 years heading	50	180

2D.6 EMISSION RATES

2D.6a If you completed Step 2D.1a, add the total available grass weight in Step 2D.1a(2) to the available litter fuel you determined in Step 2D.2c, entering the sum in the blank space below.

If you completed Step 2D.1b, enter only the available litter fuel you determined in Step 2D.2c in the blank space below.

Total fuel available: _____ ton/acre

2D.6b Perform the indicated multiplications by entering the values from the Steps shown in the following equations.

(1) Calculate ER_A, the total suspended particulate matter (TSP) emission rate (ER) for the advancing-front combustion stage:

$$ER_A = 570 \times \underset{\text{(Total fuel available from Step 2D.6a)}}{\underline{\hspace{4cm}}} \times \underset{\text{(Rate of spread from Step 2D.3d)}}{\underline{\hspace{4cm}}}$$

$$\times \underset{\text{(Consumption adjustment } (y_A) \text{ from Step 2D.4a(1))}}{\underline{\hspace{4cm}}} \times \underset{\text{(}EF_A\text{ from Step 2D.5a)}}{\underline{\hspace{3cm}}}$$

ER_A = _____ μg TSP/m-sec

(2) If your prescription is for a backing fire in any age rough, or for a heading fire in rough 2 years old or less, skip directly to Step 2D.6c.

If your prescription is for a heading fire in rough more than 2 years old, calculate ER_R, the TSP emission rate (ER) for the residual combustion stage:

$$ER_R = 570 \times \underset{\text{(Total fuel available from Step 2D.6a)}}{\underline{\hspace{4cm}}} \times \underset{\text{(Rate of spread from Step 2D.3d)}}{\underline{\hspace{4cm}}}$$

$$\times \underset{\text{(Consumption adjustment } (y_R) \text{ from Step 2D.4a(2))}}{\underline{\hspace{5cm}}} \times \underset{\text{(}EF_R\text{ from Step 2D.5a)}}{\underline{\hspace{3cm}}}$$

ER_R = _____ µg TSP/m-sec.

(3) Now, calculate ER_{A+R}, the TSP emission rate (ER) for the convective lift phase of heading fires in rough older than 2 years:

$$ER_{A+R} = \underset{\text{(}ER_A\text{ from Step 2D.6b(1))}}{\underline{\hspace{3cm}}} + \underset{\text{(}ER_R\text{ from Step 2D.6b(2))}}{\underline{\hspace{3cm}}}$$

ER_{A+R} = _____ µg TSP/m-sec.

2D.6c If you were told to skip to this Step from Step 2D.6b(2), enter the value of ER_A from Step 2D.6b(1) in the blank below for ER_{CL}, and NONE in ER_{NCL}, below, then skip directly to Step 2D.7.

If you calculated ER_{A+R} in Step 2D.6b(3), enter the value for ER_{A+R} in the blank below for ER_{CL}, then enter the value for ER_R from Step 2D.6b(2) in the blank below for ER_{NCL}:

ER_{CL} = _____ µg TSP/m-sec

ER_{NCL} = _____ µg TSP/m-sec.

2D.7 HEAT RELEASE RATE

2D.7a Make the following entry from your written prescription:

Length of fired line _____ ft

2D.7b Using the length of fired line from the Step immediately above and the same weight of available fuel and rate-of-spread values just used in Step 2D.6b, calculate the heat release rate (HRR) for the convective-lift phase of your fire. (Heat release has negligible effect for the no-convective-lift phase.)

HRR_{CL} = 0.0012 x ____________ (Available fuel from Step 2D.6a) x ____________ (Rate of spread from Step 2D.3d)

x ____________ (Consumption adjustment (y_A) from Step 2D.4a(1)) x ____________ (Length of fired line from Step 2D.7a)

HRR_{CL} = _____ megacal/sec

NOW SKIP DIRECTLY TO STAGE #3

DECISION-LOGIC STAGE #2 APPLIED TO UNPILED LOGGING DEBRIS

You Have Been Directed Here From Worksheet Set 2A

2E.1 FUELS

2E.1a Enter here for subsequent use the following information from your inventory of the burn area:

(1) Average d.b.h. in cut timber stand _____ inches
(2) Species of timber cut (check one): Loblolly pine _____
Slash pine _____
(3) Total number cords removed from area _____
(4) Total acres in burn _____

2E.1b Using the diameter and species entries you made in Step 2E.1a (1) and (2), turn to table VI-F-12 to obtain the tons of logging residue fuel 1 inch in diameter and less per cord for your burn area, entering here:

_____ ton/cord cut

2E.1c Now, using entries you made in Step 2E.1a (3) and (4), divide the total number of cords removed entry by the total acres entry, then enter the result here:

_____ cord cut/acre

2E.1d Now, multiply the ton/cord cut entry you determined in Step 2E.1b by the number of cord cut/acre you determined in Step 2E.1c to calculate the available fuel per acre, entering the product here:

_____ ton/acre

2E.2 FUEL CONSUMPTION

2E.2a Lacking a more precise means to directly express a rate of fuel consumption for this fuel type, rate of fire spread for the fine fuels that dominate its initial spread will be used as a yardstick, and then adjusted. For this purpose, enter here the following elements affecting spread in fine fuels from your written prescription:

(1) Maximum relative humidity _____ %
(2) Surface windspeed (20-foot tower) _____ mph

2E.2b Using the relative humidity entry from Step 2E.2a (1), turn to table VI-F-3 to determine the pine needle moisture content, entering this value here:

Pine needle moisture content _____ %

2E.2c Convert your surface windspeed entered in Step 2E.2a (2) to midflame windspeed by dividing by 2.[5] Then turn to table VI-F-13 and use this converted windspeed value with the pine needle litter moisture value you determined in Step 2E.2b to determine rate of spread, entering the value here:

_____ ft/min

2E.3 COMBUSTION STAGES

2E.3a Because fire spread in fine fuels is only a yardstick by which to gauge emissions and heat yield, and because a sizable amount of the fuels will remain to smolder during the residual combustion stage, an adjustment is needed to proportion the amount of fuel available to each stage. Limited data suggest an advancing-front: residual ratio of 75:25 for fuel consumed. With this and other data available to you, select the values you judge most appropriate and enter here:

(1) Decimal fraction of fuel consumed in advancing-front stage (y_A) _____

(2) Decimal fraction of fuel consumed in residual stage (y_R); (1.00 - advancing-front stage) _____

2E.4 EMISSION FACTORS

2E.4a A total suspended particulate matter (TSP) emission factor (EF_A) of 35 pounds per ton of fuel consumed is suggested for the advancing-front stage. The suggested EF_R for the residual stage is 180 pounds TSP per ton of fuel consumed. As covered in Chapter IV, these values are appreciably higher than laboratory-determined values, but are suggested at this time as a conservative representation of the best overall information available.

From this information, select emission factors (EF) for your prescribed burn and enter here:

(1) EF_A = _____ lb TSP/ton

(2) EF_R = _____ lb TSP/ton

---

[5] A factor of 2 is used rather than 4, as in understory burns, because harvesting has removed sheltering trees.

2E.5 EMISSION RATES

2E.5a Using the determined values from the Steps shown in the equations that follow, calculate emission rates (ER) by performing the indicated multiplications:

(1) For the advancing-front stage:

$$ER_A = 570 \times \underset{\text{(Available fuel from Step 2E.1d)}}{\underline{\qquad\qquad}} \times \underset{\text{(Rate of spread from Step 2E.2c)}}{\underline{\qquad\qquad}}$$

$$\times \underset{\text{(Consumption adjustment } (y_A) \text{ from Step 2E.3(1))}}{\underline{\qquad\qquad}} \times \underset{\text{(}EF_A\text{ from Step 2E.4a(1))}}{\underline{\qquad\qquad}}$$

ER_A = _____ μg TSP/m-sec

(2) For the residual stage:

$$ER_R = 570 \times \underset{\text{(Available fuel from Step 2E.1d)}}{\underline{\qquad\qquad}} \times \underset{\text{(Rate of spread from Step 2E.2c)}}{\underline{\qquad\qquad}}$$

$$\times \underset{\text{(Consumption adjustment } (y_R) \text{ from Step 2E.3a(2))}}{\underline{\qquad\qquad}} \times \underset{\text{(}EF_R\text{ from Step 2E.4a(2))}}{\underline{\qquad\qquad}}$$

ER_R = _____ μg TSP/m-sec

(3) Now, calculate ER_{A+R}, the TSP emission rate for the convective-lift phase of your fire:

$$ER_{A+R} = \underset{\text{(}ER_A\text{ from Step 2E.5a(1))}}{\underline{\qquad\qquad}} + \underset{\text{(}ER_R\text{ from Step 2E.5a(2))}}{\underline{\qquad\qquad}}$$

ER_{A+R} = _____ μg TSP/m-sec

2E.5b Enter again in the ER_{CL} blank below the value of ER_{A+R} you just calculated in Step 2E.5a(3). Then enter in the ER_{NCL} blank the value of ER_R you calculated in Step 2E.5a(2).

ER_{CL} = _____ μg TSP/m-sec

ER_{NCL} = _____ μg TSP/m-sec.

2E.6 FIRING PATTERN AND FIRED-LINE LENGTH

2E.6a From your written prescription, enter here your prescribed primary firing pattern (check one, then go to indicated Steps):

Ring firing _____ (if checked, skip to Step 2E.6c)
Heading fire _____ (if checked, proceed to Step 2E.6b)

2E.6b Use planned length of fired line without further adjustment, entering length from your written prescription here:

_____ ft

Now skip directly to Step 2E.7.

2E.6c Determine an equivalent to fired line length by following the rule-of-thumb procedure outlined in the Southern Forestry Smoke Management Guidebook Chapter IV. Enter the equivalent determined here:

_____ ft

2E.7 HEAT RELEASE RATE

2E.7a Using the determined values from the Steps shown in the equation that follows, calculate the convective-lift phase heat release rate (HRR_{CL}) by performing the indicated multiplications. (Heat release is of negligible effect for the no-convective-lift phase.)

HRR_{CL} = 0.0012 x ____________ (Available fuel from Step 2E.1d) x ____________ (Rate of spread from Step 2E.2c)

x ____________ (Consumption adjustment (y_A) from Step 2E.3a(1)) x ____________ (Length of fired line from Step 2E.6b or or 2E.6c)

HRR_{CL} = _____ megacal/sec

NOW GO DIRECTLY TO STAGE #3

DECISION-LOGIC STAGE #3: LONG-RANGE MARGIN
You Have Been Directed Here from Stage #2

3.1 FUEL TYPE

3.1a Is the fuel type selected to describe your planned burn unpiled pine logging debris or palmetto-gallberry over 2 years old, or for other fuel types will your convective-lift fire phase last to a time 3 hours before sunset?

NO _____ (skip directly to Stage #4)
YES _____ (proceed to Step 3.2a)

3.2 DETERMINATION OF TOTAL EMISSION RATE, qL

3.2a Enter here again the length of fired line (or its equivalent if determined in Step 2E.6c):

L = _____ ft

Now convert this length in feet to length in meters (multiply feet by 0.3048), entering the converted length here:

L = _____ meters

3.2b Refer back to your Worksheet Set 2B or 2E for the value of ER_{NCL} (which equals q), entering this value again here (if ER_{NCL} not calculated, substitute ER_{CL}):
q = ER_{NCL} = ______ μg TSP/m-sec

3.2c Multiply the entry for L *in meters* (not feet) from Step 3.2a times ER_{NCL} in Step 3.2b for a value of qL, entering the result here:

qL = _____ μg TSP/sec

3.3 SAFETY MARGIN

3.3a From your written prescription, enter here the transport windspeed:

_____ m/sec

3.3b (1) Using the metric value qL you entered in Step 3.2c and the transport windspeed you entered in 3.3a, refer to figure VI-M-1 to determine if the intersection of these two values is in the *safe* or *unsafe* portion of the graph.

If *safe*, it is likely your fire will not result in a long-range (>100 km or 62 miles) concentration greater than 150 $\mu g/m^3$. Which did you determine?

Safe _____ (skip directly to Stage #4)
Unsafe _____ (proceed to Step 3.3b(2))

3.3b (2) Because your long-range transport calculation indicates a risk that the concentration will exceed 150 $\mu g/m^3$ at or beyond 100 km (62 miles), you are redirected to Stage #1 to rewrite the prescription. *NOTE:* If possible, change time of burn for fuel types other than palmetto-gallberry or unpiled pine logging debris, or it may be desirable to modify the prescribed length of fired line or equivalent as a quick way of reducing the qL value, but bear in mind that this will also reduce the HRR_{CL} value with an effect on plume rise, considered later.

DECISION-LOGIC STAGE #4: MATCHING PRESCRIPTIONS TO TYPICAL CASES
You Have Been Directed Here from Stage #3

4.1 SELECTION OF TYPICAL CASE

4.1a To arrive at a set of easily used typical cases rather than an extremely large number of complex tables and computations, it has been necessary to fix certain variables. To use the procedure, you must now either conform your written prescriptions to at least equal those variables that are fixed or you must make a series of adjustments to the typical-case concentrations in order to match your burn situation. All adjustments and all prescribed elements that are more favorable to dispersion than typical will result in overestimates of tabular concentrations (i.e., the estimates are conservative).

NOTE: In this and all succeeding steps, complete no-convective-lift phase only for those burning situations for which you calculated an ER_{NCL} in Stage #2.

Turn now to table VI-M-1 to find the typical case (by fuel type) most closely matching yours, entering the case number here:

Convective-lift phase ______________
(Typical case no.)

No-convective-lift phase ______________
(Typical case no.)

4.2 MATCHING FIXED PRESCRIPTION ELEMENTS

4.2a In this Step, you will have a match to start with, will modify your prescription to match fixed variables, or will indicate a match cannot be made. For each of the following, enter your prescribed value:

Convective-lift phase[6]: Stability class _____
Mixing height _____m

No-convective-lift phase: Stability class _____
Mixing height _____m

4.2b For each of the following, indicate which answer applies.

(1) Column 2: Stability class must be at least as good as shown in table VI-M-I.[7] Indicate how your prescription matches (check one in each phase):

---

[6] For actual day of burn, if National Weather Service is not furnishing stability class, see Southern Forestry Smoke Management Guidebook Chapter V for a method of determining stability class in the field.

[7] Note stability classes decrease in ability to help smoke dispersion as these scale from A to D (i.e., A is better than B, etc.). Classes shown as typical are more likely to be encountered.

	Convective-lift phase	No-convective-lift phase
Matched or is better	_____	_____
Made to match	_____	_____
Is not as good as and cannot be made to match	_____	_____

(2) Column 3: Mixing height must be higher than or at least within 300 meters of the value shown as typical in table VI-M-1. Indicate how your prescription matches (check one in each phase):

	Convective-lift phase	No-convective-lift phase
Matched or is better	_____	_____
Made to match	_____	_____
Is not as good as and cannot be made to match	_____	_____

4.2c In both (1) and (2) of Step 4.2b, did you check that a match could be made? (check only one):

YES (both matched or made to match) _____

Skip to Step 4.3a

NO (one or both variables cannot be made to match) _____

If a match cannot be made, we recommend that you arrange for a computer-assisted analysis for determining the best combination of prescription elements. Is this possible?

YES _____ (If this is possible, proceed directly to Stage #6)

NO _____ (If not possible, you will run a risk of causing or contributing to a pollution episode under your present prescription An alternative to burning is recommended.)

4.3 OTHER VARIABLES AND CORRECTION FACTORS

4.3a Each of the following variables can be made to match the typical case by correction factors. First enter here for subsequent use the values shown in your written prescription for transport windspeed:

Convective-lift phase _____m/sec No-convective-lift phase _____m/sec

4.3b Now enter the crosswind length of fired line from your prescription. (*NOTE*: Do not use the fired-line equivalent for logging debris from Step 2E.6c here. For this calculation, the crosswind width of the fired area is needed in order to arrive at plume width.)

(1) _____ ft

And then convert this value to meters by multiplying feet by 0.3048, entering the conversion here:

(2) _____ m

4.3c Enter here values from that portion of Stage #2 you completed:

(1) Convective-lift phase heat release rate
HRR_{CL} _____ megacal/sec

(2) Emission rates (ER)
ER_{CL} _____ μg/m-sec

ER_{NCL} _____ μg/m-sec

4.3d In this Step, you will derive individual correction factors for each of the above variables by comparing your entries with typical values in table VI-M-1. (These will be used to the nearest 1/10th in Step 4.4a to develop a single correction factor.)

(1) TRANSPORT WINDSPEED. Calculate a correction factor for transport windspeed by dividing the table VI-M-1 typical-case value by the value you entered in Step 4.3a, entering the result here (if values are equal, enter 1.0):

Convective-lift phase _____ No-convective-lift phase _____

(2) HEAT RELEASE RATE. Is the heat release rate (HRR_{CL}) you entered in Step 4.3c equal to or greater than the table VI-M-1 column #4 typical case? (check one):

If YES, $\geq$ _____, enter 1.0 below

If NO, < _____, enter a worst-case correction factor of 1.4 below

Correction factor _____

(3) CONVECTIVE-LIFT PHASE EMISSION RATE. Calculate a correction factor for convective-lift phase emission rate (ER_{CL}) by dividing your ER_{CL} from Stage #2 by the table VI-M-1 typical case ER_{CL}, entering the result here (if your ER_{CL} is the same as the typical case ER_{CL}, enter 1.0):

Correction factor = $\underset{(\text{Stage \#2 } ER_{CL})}{\underline{\qquad\qquad}} \div \underset{(\text{Typical } ER_{CL})}{\underline{\qquad\qquad}} =$ _____

(4) NO-CONVECTIVE-LIFT PHASE EMISSION RATE. Calculate a correction factor for the no-convective-lift phase emission rate (ER_{NCL}) by dividing your ER_{NCL} from Stage #2 by the table VI-M-1 typical case ER_{NCL}, entering the result here (if your ER_{NCL} is the same as the typical case ER_{NCL}, enter 1.0):

Correction factor = ______________ ÷ ______________ = ______

(Stage #2 ER_{NCL}) (Typical ER_{NCL})

(5) FIRED-LINE LENGTH. Is the crosswind length of fired line in Step 4.3b(2) less than or equal to the table VI-M-1 column #5 typical-case length?

If YES, check here then enter 1.0 for a correction factor for all distances in the spaces below

______

If NO, check here then turn to table VI-M-6 and list in the spaces below the given correction factors for each distance

______

Downwind Distances (km)	Downwind Distances (miles)	Crosswind fired-line length correction factors (nearest 1/10th)
0.10	.06	
.13	.08	
.16	.10	
.20	.12	
.25	.16	
.32	.20	
.40	.25	
.50	.31	
.63	.39	
.79	.49	
1.00	.62	
1.30	.81	
1.60	.99	
2.00	1.24	
2.50	1.55	
3.20	2.00	
4.00	2.50	
5.00	3.11	
6.30	3.92	
7.90	4.91	
10.00	6.21	
13.00	8.08	
16.00	9.94	
20.00	12.43	
25.00	15.53	
32.00	19.88	
40.00	24.86	
50.00	31.07	
63.00	39.15	
79.00	49.09	
100.00	62.14	

4.4 COMBINING CORRECTION FACTORS AND MAKING CORRECTIONS

4.4a Now calculate combined correction factors (nearest 1/10th) to be used at each distance for each fire phase as follows:

(1) Enter here and multiply the following convective-lift phase factors:

______	x	______	x	______	=	______
(Transport windspeed factor from Step 4.3d(1))		(HRR_{CL} factor from Step 4.3d(2))		(ER_{CL} factor from Step Step 4.3d(3))		(Result, CL phase

Then use the convective-lift phase multiplication result immediately above to multiply *each* line-length correction factor listed in Step 4.3d(5), entering the final multiplication result in column (B) of the blank table that follows Step 4.4b.

(2) If you are carrying forward a no-convective-lift phase, enter here and multiply the following no-convective-lift factors:

____________________	x	______________	=	__________________
(Transport windspeed factor from Step 4.3d(1))		(ER_{NCL} factor from Step 4.3d(4))		(Result, NCL phase)

Then use the no-convective-lift phase multiplication result immediately above to again multiply *each* line-length correction factor listed in Step 4.3d(5), entering the final multiplication result in column (D) of the blank table which follows Step 4.4b.

4.4b Use the same typical-case numbers you entered in Step 4.1a to again refer to table VI-M-1, column 8, for the appropriate concentration tables to use next. Enter here the tables to be used.

Convective-lift-phase concentration table VI-M-______

No-convective-lift phase concentration table VI-M-______

Next use the concentration tables you just selected as follows for the worktable immediately below:

(1) Opposite each distance, and in the column that fits your burning situation, read the typical-case concentration, entering it in column (C) for convective-lift phase, or in column (E) for no-convective-lift phase of the worktable which follows.

(2) Now multiply each typical-case concentration entry in the following worktable by its correction factor, and enter the result in the corrected concentration columns, (C') (E'), for convective-lift and no-convective-lift phases, respectively, in the worktable.

(A) Downwind distances		Convective-lift phase			No-convective-lift phase[1]		
(km)	(miles)	(B) Correction factor	(C) Typical-case concentration	(C') Corrected concentration	(D) Correction factor	(E) Typical-case concentration	(E') Corrected concentration
0.10	.06						
.13	.08						
.16	.10						
.20	.12						
.25	.16						
.32	.20						
.40	.25						
.50	.31						
.63	.39						
.79	.49						
1.00	.62						
1.30	.81						
1.60	.99						
2.00	1.24						
2.50	1.55						
3.20	2.00						
4.00	2.50						
5.00	3.11						
6.30	3.92						
7.90	4.91						
10.00	6.21						
13.00	8.08						
16.00	9.94						
20.00	12.43						
25.00	15.53						
32.00	19.88						
40.00	24.86						
50.00	31.07						
63.00	39.15						
79.00	49.09						
100.00	62.14						

---

[1] Complete only for those burning situations where you calculated an ER_{NCL} for the no-convective-lift phase in Section 2.

NOW PROCEED TO STAGE #5.

DECISION-LOGIC STAGE #5: PLOTS OF CONCENTRATION, COMPARISONS, MODIFICATIONS, AND MULTIPLE-SOURCE ANALYSIS

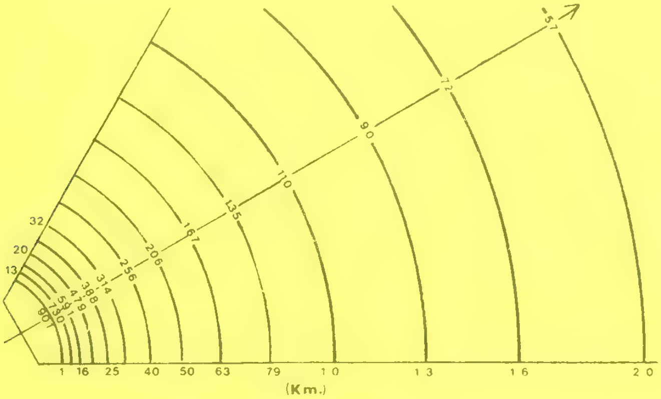
5.1 PLOTTING ZONES OF CONCENTRATION

5.1a Using a drawing compass, set it to scale for each distance in Column (A) of the Worktable you just completed in Step 4.4b, and strike distance arcs on the trajectory plots you made on the map in Steps 1.1(1) and (2) as follows:

Until the distance from the fire is twice the length of the fired line, strike two arcs--one centered at each end of the fired line--then connect them by a straight line parallel to the fired line. After the distance from the fire is twice the fired-line length, strike only one arc centered at the intersection of the fired line with the plume centerline.

NOTE: If target backgrounds are low and multiple fires are not expected, you need to plot arcs only to the distances where your corrected concentrations (Step 4.4b, Columns (C') and (E')) will be of importance. If important distances are within 2 kilometers, a plot on a separate, large-scale map will be desirable.

5.1b Now use the same two colors for the combustion stages that you used in Step 1.1a to write the corrected concentrations from the Worktable in Step 4.4b on your map at each corresponding distance arc. A completed trajectory plot with zones on concentration will look like this:



5.2 COMPARING CRITICAL TARGET ACCEPTABLE CONCENTRATIONS WITH PREDICTED TOTAL CONCENTRATIONS

5.2a Starting in the map area with the highest zone of concentration and working toward zones of lower concentrations, select the most critical targets expected to experience the concentrations plotted. List these selected targets one at a time in Column (A) of the Worktable immediately below, entering the corresponding values the table calls for at the time you list each target. The following instructions apply to determining values for entries called for by the Worktable.

Column (B) - Applicable Smoke Concentration Zone Value.--For targets directly on an arc, use the concentration zone value shown with the arc. For targets falling between two arcs, always use the higher of the two concentrations unless you interpolate logarithmically.

Column (C) - Expected Background Concentration at Target.--Entries in this column must be for the time of year for which a planned burn prescription is being applied to this logic procedure or must be actual. These can be obtained, in some cases, from air quality personnel; or lacking this help, a rule of thumb will give you an expected particulate matter concentration based upon the expected visibility (which can be drawn from experience, airport climatological records, or local residents). It is based upon the relationship:

730 μg-miles/m^3 ÷ miles of visibility = TSP concentration in $\mu g/m^3$.

Some typical values are:

25-mile visibility = 29 $\mu g/m^3$; 20-mile visibility = 36 $\mu g/m^3$;
15-mile visibility = 49 $\mu g/m^3$; 10-mile visibility = 73 $\mu g/m^3$;
5-mile visibility =146 $\mu g/m^3$; 2-mile visibility =365 $\mu g/m^3$.

Column (D) - Predicted Total Concentration.--The entry for this column is simply the sum of the value entered in Column (B) and the value entered in Column (C).

Column (E) - Maximum Acceptable Concentration.--This entry is best obtained from local air quality personnel. Lacking this help, it is suggested you use a visibility criterion and the same rule of thumb as was suggested in the Column (C) instructions above. In this case, you set the minimum visibility you believe will be acceptable (*CAUTION*: This is reportedly rarely less than 5 miles), then enter the corresponding concentration. EXAMPLE: 10-mile visibility is believed to be the minimum below which public complaints will be raised; then the corresponding maximum acceptable concentration entry is 73 $\mu g/m^3$, (730 ÷ 10).

WORKTABLE

(A) Target name or other identifier	(B) Applicable smoke concentration zone value		(C) Expected background concentration at target	(D) Predicted total concentration Col. (B) + Col. (C)		(E) Maximum acceptable concentration
	CL phase	NCL phase		CL phase	NCL phase	

5.2b Now compare the Column (E) entries with both the convective-lift and no-convective-lift phase entries in Column (D).

Is the predicted total concentration less than the maximum acceptable concentration for all entries? (check for each phase)

Convective-lift phase	No-convective-lift phase
Yes ______________	Yes ______________
No ______________	No ______________
	Not applicable ________

5.2c (1) If you checked YES for applicable phases above and do not anticipate that other burns may contribute to concentrations in target areas, check here and STOP using logic at this point. PROCEED WITH YOUR BURN.

____

(2) If you checked YES for applicable phases above but anticipate other prescribed burns may contribute to concentrations in target areas and want to run a further analysis, check here and skip to Step 5.4.

____

OR, if you do not want to skip to Step 5.4 check here and STOP using logic.

____

PROCEED WITH YOUR BURN ONLY IF YOU WANT TO RISK POSSIBLE TARGET-AREA CONCENTRATIONS IN EXCESS OF DESIRED NET.

(3) If you checked NO in either phase, proceed to Step 5.3.

5.3 DETERMINING WHICH PRESCRIPTION VARIABLES TO MODIFY

5.3a Look back to the Worktable you completed in Step 5.2a for the worst case (i.e.: greatest amount Column (D) exceeds Column (E)).

Now divide the Column (D) entry by the Column (E) entry, entering the result of division here:

____

(1) If the result of division is less than 2, your chance of making a desk-top revision of your prescription for an acceptable concentration is good. Check here and skip directly to Step 5.3b.

____

(2) If the result of division is less than 5, there is a chance of making an acceptable revision of your prescription--but repeated trials are likely to be needed, and a Stage #6 analysis will be most desirable.

If you can arrange for assistance with a Stage #6 automatic data processing analysis, check here and STOP further work on Phase #5. ______

If you cannot arrange for assistance, you may elect to try a desk-top revision and should skip directly to Step 5.3b after checking here. ______

If you cannot arrange for assistance and do not elect to try a desk-top revision, skip directly to Step 5.3g after checking here. ______

(3) If the result of division is greater than 5, skip directly to Step 5.3g after checking here. ______

5.3b If your prescription calls for a heading fire, first consider revising the prescription to call for a backing fire. Check here, then proceed to Step 5.3c BEFORE modifying your prescription. ______

5.3c Examine the correction factors you calculated in Stage #4, entering a check here for each that is greater than 1.0.

Variable	Calculated in Step	Convective-lift phase factor (✓)	No-convective-lift phase factor (✓)
Transport windspeed	4.3d(1)		
Length of fired line	4.3d(2)		
HRR_{CL}	4.3d(3)		Not applicable
ER_{CL}	4.3d(4)		Not applicable
ER_{NCL}	4.3d(5)		

5.3d If any of the above checked factors include transport windspeed and/or fired-line length factors, you will next want to modify your prescription to lower these. The fired-line length correction factor is lowered by shortening the prescribed fired-line length. The transport windspeed correction factor is lowered by increasing the prescribed speed. NOTE: For this analysis, it will not benefit your calculations to reduce the fired-line length below that used in the typical case (see table VI-M-1). Check here, then proceed to Step 5.3e BEFORE modifying your prescription. ______

5.3e If your exceeded allowable concentration is only in the convective-lift phase and your heat release rate correction factor is checked in Step 5.3c, this is the next prescription item to consider modifying. Before deciding to do so, make sure the emission rate correction factor IS NOT also checked. HRR_{CL} is best increased, resulting in a lower correction factor, by increasing rate of spread (which is a function of lower fine fuel moisture and higher surface windspeed). These, however, will all increase emission rate, which can offset your gains. Check here and then proceed to Step 5.3f BEFORE modifying your prescription.

5.3f Now, having considered the instructions in Steps 5.3b through 5.3e, list here any variables you intend to modify in your prescription. Then use a colored pencil to enter new values in the prescription and in the preceding Stages #2 through #5, Steps 5.1 and 5.2, reworking all dependent calculations and comparisons until you have again arrived at Step 5.3. If there are no variables that can be modified, enter NONE, then proceed to Step 5.3g.

Variables to be modified

____

____

____

____

CAUTION: Do not simply modify the prescription and then use new correction factors in Stage #4. Many of the variables are interdependent, resulting in offsetting changes. Hopefully, after reworking Stages #2 through #4 and Steps 5.1 and 5.2, you will be able to skip to Step 5.3 on the next pass through!

5.3g You have arrived at this Step either because of too great a difference between predicted total concentration and maximum acceptable concentration, or because of computational difficulties that cannot be remedied.

If this is the case, you may wish to consider exploring exceeded maximum acceptable concentrations at some targets for a very short time period. By limiting the dimension of the burn area which is on the same azimuth as the transport wind direction, the duration is limited. For example: Wind at right angle to road. A 200-foot-wide burned area will at least provide a good fuel break. If instead of burning the entire tract you burn to a 200-foot limit, the time of high smoke concentration will be shortened and you may be able to work with local authorities to provide traffic control for safety on the road for the short period this size burn would take to burn out. Other than this, you may need to select a treatment alternative other than fire.

Enter your decision here and STOP using the logic procedure:

____

____

____

5.4 RUDIMENTARY MULTIPLE-SOURCE ANALYSIS

5.4a This Step is for conducting a rudimentary multiple-source analysis if there is a likelihood that more than your prescribed burn will contribute to target concentrations.

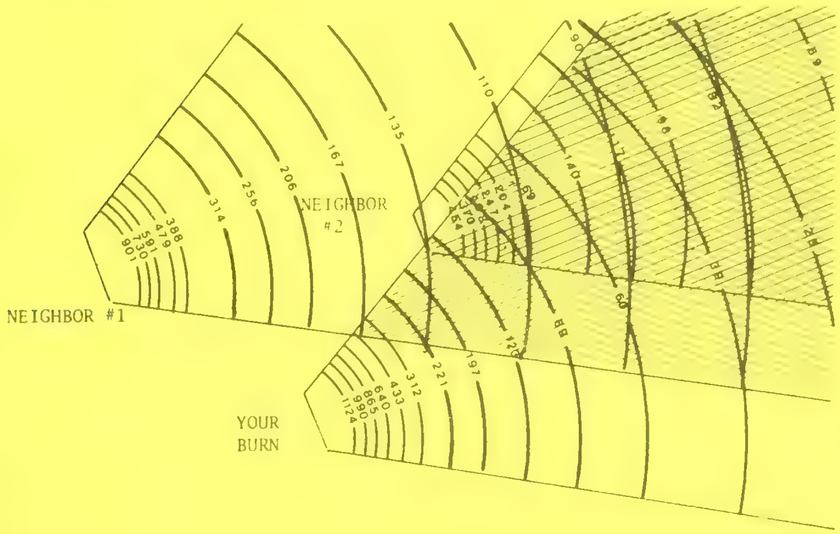
For all such suspect simultaneous sources, follow this procedure:

(1) For each, plot the trajectory and 30° deviations as you did in Steps 1.1a (1) and (2).

(2) For all those where the 30° deviations overlap with those from this burn, it will be most desirable to have available completed, separate analyses such as this. If not available, use either the final trajectory plots from Step 5.1b of this burn again, or simply use the unadjusted values from a typical case (see table VI-M-1 and corresponding tables), whichever comes closest.

(3) With the new burn trajectory(s) plotted to show arcs as zones of concentration, as you did for this burn, you can now sum the zones in all overlapping areas to prepare a mutual targets worktable in the same format as you did in Step 5.2a for this burn alone.

EXAMPLE:



In this example, the applicable concentration zone values, relating two neighbors' burns to your burn, become:

Your burn alone	Your burn and neighbor #1	All three burns
1,124		
990		
865		
640		
433	433 + 167	
312	312 + 167	
221	221 + 167	
221	221 + 135	
197	197 + 167	
197	197 + 135	
123	123 + 135	123 + 135 + 454
123	123 + 135	123 + 135 + 370
123	123 + 135	123 + 135 + 303
123	123 + 135	123 + 135 + 247
123	123 + 135	123 + 135 + 204
88	88 + 135	88 + 135 + 204
88	88 + 135	88 + 135 + 169
88	88 + 110	88 + 110 + 169
88	88 + 110	88 + 110 + 140
60	60 + 110	60 + 110 + 169
60	60 + 110	60 + 110 + 140
60	60 + 110	60 + 110 + 117
60	60 + 90	60 + 90 + 117
60	60 + 90	60 + 90 + 98
39	39 + 90	39 + 90 + 117
39	39 + 90	39 + 90 + 98
39	39 + 82	39 + 82 + 82
25	25 + 82	25 + 82 + 90
25	25 + 82	25 + 82 + 82
25	25 + 82	25 + 82 + 69

DECISION-LOGIC STAGE #6: AUTOMATIC DATA PROCESSING ASSISTED ANALYSIS

This Stage is under development at this time and will be issued later. The following is a brief outline of what is planned:

1. *A program in FORTRAN for use on any compatible computer.*--This program will be printed as a "separate" that can be inserted into copies of the Sourcebook. With the program, rapid reiterations of combinations of variables now made by hand in Stages #2 through #5 will be possible. Hence, the user will be able to quickly select the best of his prescription options. Instructions for use will also be printed as a "separate" that can be inserted into copies of the Guidebook.

2. *An adaptation of the above program for use in a central computer.*--Data from spot weather forecasts would be entered, along with user inputs to determine likely downwind concentrations.

3. *A refined system for analyzing the effects of multiple forestry emissions sources on air quality.*

PART 3. TABLES

The tables that follow are for use with the Steps in the preceding instructions. Sources of these tables are discussed in preceding chapters—fuel and fire behavior tables (VI-F-1 through VI-F-13, printed on pink paper) in Chapter IV and meteorology tables and figure (tables VI-M-1 through VI-M-6 and fig. VI-M-1 printed on blue paper) in Chapter V. For the convenience of users and to permit periodic updating, each table is presented on a separate page.

Table VI-F-1. — Effect of age of rough on total available grass accumulations under pine overstories

Age of rough (years)	Total available grass accumulation
	Tons per acre
1	1.86
2	1.00
3	.71
4	.57
5	.48
10	.31
15	.26
20	.23
25	.21

Table VI-F-2. — Fine fuel moisture content of dead grass (1-hour timelag)

Cloud cover and dry bulb temperature 1/ (°F)	Relative humidity									
	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74
					Percent					
Sunny:										
10-29	5	5	6	7	8	8	8	9	9	10
30-49	5	5	6	7	7	7	8	9	9	10
50-69	5	5	6	6	7	7	8	8	9	9
70-89	4	5	5	6	7	7	8	8	8	9
Cloudy:										
10-29	6	7	8	9	10	11	12	12	14	15
30-49	6	7	8	9	9	11	11	12	13	14
50-69	6	6	8	8	9	10	11	11	12	14
70-89	5	6	7	8	9	10	10	11	12	13

1/Adapted from Deeming and others (1972).

Purpose. — To compute the fine fuel moisture content of dead grass 0.25 inch and less in diameter.

Procedure. — Use "cloudy" if there is 60 to 90 percent cloud cover; an overcast covering more than 90 percent of the sky; fog, showers, or thunderstorms in the vicinity; or if the observation is being taken before 10:00 a.m. or after 3:00 p.m. local standard time. "Sunny" covers all other conditions.

Table VI-F-3.— Moisture content of pine needle litter [1]

Relative humidity (percent)	Moisture content
	Percent
25 to 29	8
30 to 34	8
35 to 39	9
40 to 44	9
45 to 49	10
50 to 54	11
55 to 59	12
60 to 64	13
65 to 69	15
70 to 74	17

[1] Based on Blackmarr (1971).

Table VI-F-4. — Expected rate of fire spread in grass fuels 1/ 2/ as a function of midflame windspeed and fine fuel moisture content where land slopes do not exceed 20 percent

Midflame windspeed 3/ (miles per hour)	Rate of spread					
	Fine fuel moisture (percent)					
	4	6	8	12	16	20
	Feet per minute					
0	5	4	4	3	3	2
1	11	9	8	6	6	5
2	25	21	18	14	13	11
3	45	37	32	26	23	19
4	71	59	50	41	36	30
5	101	84	72	59	51	43
6	137	114	98	79	69	58

1/ Adapted from Rothermel (1972).

2/ Factors used in Rothermel's (1972) equation:

$W_o = 0.088$ lb/ft^2 MCE = 30

d = 1.0 WS = 0, 1, 2, 3, 4, 5, 6

s/v = 2,500 MC = 4, 6, 8, 12, 16, 20

mc = 0.0555 HV = 8,000

sc = 0.01 DEN = 32

3/ Under a tree canopy, midflame windspeed can be estimated by using windspeed values from the nearest 20-foot, open-tower installation and dividing that value by 4.

Table VI-F-5. — Total litter weight under slash pine stands as affected by stand basal area and age of rough [1]

Stand basal area (square feet per acre)	Age of rough (years)								
	1	2	3	4	5	7	10	15	20
					Tons per acre				
30	1.5	2.5	3.4	4.2	4.8	5.9	7.0	8.1	8.4
50	1.6	2.8	3.8	4.7	5.4	6.6	7.9	9.0	9.4
70	1.8	3.2	4.3	5.2	6.1	7.4	8.8	10.1	10.5
90	2.1	3.5	4.8	5.9	6.8	8.3	9.9	11.3	11.7
110	2.3	4.0	5.4	6.6	7.6	9.3	11.1	12.7	13.2
130	2.6	4.4	6.0	7.3	8.5	10.4	12.4	14.2	14.7
150	2.9	5.0	6.7	8.2	9.5	11.6	13.9	15.9	16.5
175	3.3	5.7	7.7	9.5	11.0	13.4	16.0	18.3	19.0
200	3.8	6.6	8.9	10.9	12.6	15.4	18.4	21.1	21.9

[1] Applies to stands with or without understory vegetation (McNab and Edwards 1976).

Table VI-F-6. — Total litter weight under loblolly pine stands as affected by stand basal area and age of rough

Stand basal area (square feet per acre)	Age of rough (years)							
	1	2	3	4	5	7	10	15
	Tons per acre							
30	1.4	2.2	2.9	3.4	3.8	4.5	4.7	4.7
50	1.5	2.4	3.2	3.9	4.3	5.0	5.3	5.3
70	1.6	2.8	3.7	4.3	4.8	5.6	5.9	5.9
90	1.9	3.0	4.1	4.8	5.4	6.3	6.6	6.6
110	2.1	3.5	4.6	5.4	6.0	7.1	7.4	7.4
130	2.4	3.8	5.1	6.0	6.7	7.9	8.3	8.3
150	2.7	4.3	5.7	6.7	7.5	8.8	9.3	9.3
175	3.0	5.0	6.6	7.8	8.7	10.2	10.7	10.7
200	3.5	5.8	7.6	8.9	10.0	11.7	12.3	12.3

Table VI-F-7. — Estimated available litter fuel weights for different total litter weights and moisture contents[1]

Total litter weight (tons per acre)	Total litter layer moisture content (percent)										
	10	20	40	60	80	100	120	140	160	180	200
	Tons per acre										
2	1.2	1.0	0.5	–	–	–	–	–	–	–	–
4	3.4	3.1	2.7	2.2	1.7	1.2	0.8	0.3	–	–	–
6	4.6	4.4	3.9	3.4	3.0	2.5	2.0	1.5	1.1	0.6	0.1
8	5.6	5.4	4.9	4.4	4.0	3.5	3.0	2.5	2.1	1.6	1.1
10	6.5	6.3	5.8	5.3	4.9	4.4	3.9	3.4	3.0	2.5	2.0
12	7.4	7.1	6.7	6.2	5.7	5.2	4.8	4.3	3.8	3.3	2.8
14	8.2	8.0	7.5	7.0	6.6	6.1	5.6	5.1	4.7	4.2	3.7
16	9.0	8.8	8.3	7.8	7.4	6.9	6.4	5.9	5.5	5.0	4.5

[1] Based on unpublished data on file at the Southern Forest Fire Laboratory, Southeastern Forest Experiment Station, USDA Forest Service, Macon, Ga.

Table VI-F-8. — Expected rate of fire spread in pine needle and low brush fuels1/ 2/ as a function of midflame windspeed and pine needle litter moisture content where land slopes do not exceed 20 percent

Midflame windspeed 3/ (miles per hour)	Rate of spread				
	Pine needle litter moisture content (percent)				
	6	8	12	16	20
	Feet per minute				
0	1	1	1	1	1
1	2	2	2	1	1
2	5	4	3	3	2
3	7	6	5	4	4
4	10	9	7	6	5
5	13	11	9	8	7
6	16	14	11	10	8

1/ Adapted from Rothermel (1972).

2/ Factors used in Rothermel's (1972) equation:

W_0 = 1.25 ton/acre = 0.057 lb/ft^2

d = 0.25 (3 inches)

s/v = 1,500

mc = 0.04 (min. content)

sc = 0.01

MCE = 0.40

WS = 0, 1, 2, 3, 4, 5, 6

MC = 6, 8, 12, 16, 20

HV = 8,000

DEN = 26

3/ Under a tree canopy, midflame windspeed can be estimated by using windspeed values from the nearest 20-foot, open-tower installation and dividing that value by 4.

Table VI-F-9. — Understory vegetative dry weight in the palmetto-gallberry type as related to age of rough and understory height

Understory height (feet)	Age of rough (years)							
	1	2	3	5	7	10	15	20
	Tons per acre							
1	0.4	0.4	0.5	0.6	0.9	1.4	2.6 1/	4.2 1/
2	1.2	1.3	1.3	1.5	1.7	2.2	3.4 1/	5.1 1/
3	2.6	2.6	2.7	2.8	3.1	3.5	4.7	6.4
4	4.5 1/	4.5	4.6	4.7	5.0	5.5	6.6	8.3
5	7.0 1/	7.0 1/	7.0	7.2	7.4	7.9	9.1	10.8
6	10.0 1/	10.0 1/	10.0 1/	10.2	10.4	10.9	12.1	13.8

1/ Represents a situation not likely to be found in nature.

Table VI-F-10. — Estimated total available fuel (litter + vegetation) as a function of total litter layer moisture content, total litter weight, and understory vegetative dry weight

Understory vegetative dry weight (tons per acre)	Total available fuel (litter + vegetation)										
	Total litter weight in tons per acre										
	1	2	3	4	5	6	8	10	12	14	16
	Tons per acre										
10 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	2.0	3.2	4.1	4.8	5.4	6.5	7.5	8.4	9.3	10.2
3	.4	3.3	4.6	5.5	6.1	6.7	7.8	8.8	9.8	10.7	11.6
5	1.7	4.7	5.9	6.8	7.5	8.1	9.2	10.2	11.1	12.0	12.9
7	3.1	6.0	7.3	8.2	8.8	9.4	10.5	11.5	12.5	13.4	14.3
9	4.4	7.4	8.7	9.5	10.2	10.8	11.9	12.9	13.8	14.7	15.6
11	5.8	8.7	10.0	10.9	11.5	12.2	13.2	14.2	15.2	16.1	17.0
20 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	1.7	3.0	3.8	4.5	5.1	6.2	7.2	8.1	9.1	10.0
3	.1	3.0	4.3	5.2	5.9	6.5	7.5	8.5	9.5	10.4	11.3
5	1.4	4.4	5.7	6.5	7.2	7.8	8.9	9.9	10.8	11.8	12.7
7	2.8	5.7	7.0	7.9	8.6	9.2	10.2	11.2	12.2	13.1	14.0
9	4.1	7.1	8.4	9.2	9.9	10.5	11.6	12.6	13.5	14.5	15.4
11	5.5	8.5	9.7	10.6	11.3	11.9	13.0	13.9	14.9	15.8	16.7
40 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	1.1	2.4	3.3	4.0	4.6	5.6	6.6	7.6	8.5	9.4
3	.0	2.5	3.8	4.6	5.3	5.9	7.0	8.0	8.9	9.9	10.8
5	.9	3.8	5.1	6.0	6.7	7.3	8.3	9.3	10.3	11.2	12.1
7	2.2	5.2	6.5	7.3	8.0	8.6	9.7	10.7	11.6	12.6	13.5
9	3.6	6.5	7.8	8.7	9.4	10.0	11.0	12.0	13.0	13.9	14.8
11	4.9	7.9	9.2	10.0	10.7	11.3	12.4	13.4	14.3	15.3	16.2
80 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	0.0	1.3	2.2	2.9	3.5	4.5	5.5	6.5	7.4	8.3
3	.0	1.4	2.7	3.5	4.2	4.8	5.9	6.9	7.8	8.8	9.7
5	.0	2.7	4.0	4.9	5.6	6.2	7.2	8.2	9.2	10.1	11.0
7	1.1	4.1	5.4	6.2	6.9	7.5	8.6	9.6	10.5	11.5	12.4
9	2.5	5.4	6.7	7.6	8.3	8.9	9.9	10.9	11.9	12.8	13.7
11	3.8	6.8	8.1	8.9	9.6	10.2	11.3	12.3	13.2	14.2	15.1
120 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	0.0	0.2	1.1	1.8	2.4	3.4	4.4	5.4	6.3	7.2
3	.0	.3	1.6	2.4	3.1	3.7	4.8	5.8	6.7	7.6	8.6
5	.0	1.6	2.9	3.8	4.5	5.1	6.1	7.1	8.1	9.0	9.9
7	.0	3.0	4.3	5.1	5.8	6.4	7.5	8.5	9.4	10.4	11.3
9	1.4	4.3	5.6	6.5	7.2	7.8	8.8	9.8	10.8	11.7	12.6
11	2.7	5.7	7.0	7.8	8.5	9.1	10.2	11.2	12.1	13.1	14.0
160 PERCENT TOTAL LITTER LAYER MOISTURE CONTENT											
1	0.0	0.0	0.0	0.0	0.6	1.3	2.3	3.3	4.3	5.2	6.1
3	.0	.0	.5	1.3	2.0	2.6	3.7	4.7	5.6	6.5	7.5
5	.0	.5	1.8	2.7	3.4	4.0	5.0	6.0	7.0	7.9	8.8
7	.0	1.9	3.2	4.0	4.7	5.3	6.4	7.4	8.3	9.3	10.2
9	.3	3.2	4.5	5.4	6.1	6.7	7.7	8.7	9.7	10.6	11.5
11	1.6	4.6	5.9	6.7	7.4	8.0	9.1	10.1	11.0	12.0	12.9

Table VI-F-11. — Expected rate of fire spread [1] in palmetto-gallberry fuels as a function of midflame windspeed and pine needle litter moisture content where land slopes do not exceed 20 percent

Midflame windspeed [2] (miles per hour)	Rate of spread				
	Pine needle litter moisture content (percent)				
	6	8	12	16	20
			Feet per minute		
0	3	2	2	2	2
1	6	5	5	4	4
2	12	11	10	9	8
3	20	19	17	15	13
4	30	28	25	22	20
5	42	38	33	31	27
6	54	49	44	39	35
7	67	61	54	49	44

[1] Adapted from Hough and Albini (1976).

[2] Under a tree canopy, midflame windspeed can be estimated by using windspeed values from the nearest 20-foot, open-tower installation and dividing that value by 4.

Table VI-F-12. — Available fuel 1 inch in diameter and less in the unpiled pine logging debris type

Average d.b.h. in cut stand (inches)	Undisturbed logging residue	
	Loblolly	Slash
	---- Tons per cord cut ----	
5	–	0.47
6	0.20	.30
7	.17	.24
8	.15	.21
9	.13	.21
10	.11	.23
11	.12	.28
12	.13	–
14	.11	–
16	.10	–

Table VI-F-13. — Expected rate of fire spread in broadcast southern pine logging debris (Fuel Model C) [1] as a function of midflame windspeed and pine needle litter moisture content where land slopes do not exceed 20 percent

Midflame windspeed [2] (miles per hour)	Rate of spread				
	Pine needle litter moisture content (percent)				
	6	8	12	16	20
	------------ Feet per minute ------------				
0	3	2	2	1	1
1	4	4	4	3	3
2	10	8	7	6	4
3	16	15	12	10	7
4	30	24	18	15	12
5	36	30	24	21	18
6	48	42	36	30	24
7	66	60	48	42	30
8	78	72	60	48	36
9	102	90	72	60	42
10	120	102	90	72	54

[1] National Fire-Danger Rating System classification adapted.

[2] Since this fuel type is not under a tree canopy, midflame windspeed can be estimated by using windspeed values from the nearest 20-foot, open-tower installation and dividing that value by 2.

Table VI-M-1. — Summary of variables used in compiling typical case examples in tables VI-M-2 through VI-M-5

Typical case no.	1 Typical for	2 Pasquill stability class	3 Mixing height	4 Heat release rate (HRR)	5 Length of fired line or equiv.	6 Transport windspeed	7 Emission rate (ER)	8 See concentration in table
			Meters	Megacal/sec	Meters	M/sec	µg/M-sec	
1	Grass:							
	Backing fire	C	1,500	14.112	800	8	37,800	VI-M-2
2	Grass:							
	Heading fire	C	1,500	75.624	400	8	403,200	VI-M-2
3	Pine needle litter:							
	Backing fire	C	1,500	4.704	400	8	84,000	VI-M-3
4	Pine needle litter:							
	Heading fire							
	CL phase	C	1,500	11.76	400	8	966,000	VI-M-3
	NCL phase	C	1,500	0	400	8	756,000	VI-M-3
5	Palmetto-gallberry:							
	Backing fire	C	1,500	37.632	800	8	168,000	VI-M-4
6	Palmetto-gallberry:							
	Heading fire in							
	2-year-old rough	C	1,500	137.984	800	8	616,000	VI-M-4
7	Pine logging debris:							
	In winter							
	CL phase	C	1,500	211.68	500 (eq.)	8	5,745,600	VI-M-5
	NCL phase	C	1,500	0	500 (eq.)	8	3,628,800	VI-M-5
8	Pine logging debris:							
	In summer							
	CL phase	B	2,000	70.56	500 (eq.)	5	1,915,200	VI-M-5
	NCL phase	B	2,000	0	500 (eq.)	5	1,209,600	VI-M-5

Table VI-M-2. — Particulate matter concentrations at various distances downwind for typical cases No. 1 and No. 2

Distance downwind X(km)	Concentration (χ)	
	Backing fire	Heading fire
	$\mu g/m^3$	$\mu g/m^3$
0.10	203	2,161
.13	164	1,751
.16	133	1,481
.20	108	1,149
.25	87	931
.32	71	754
.40	58	611
.50	47	495
.63	39	400
.79	31	319
1.00	26	249
1.30	21	188
1.60	18	138
2.00	17	98
2.50	15	68
3.20	12	47
4.00	10	33
5.00	8	24
6.30	5	19
7.90	4	15
10.00	3	11
13.00	2	8
16.00	2	6
20.00	1	4
25.00	1	3
32.00	0	2
40.00	0	2
50.00	0	2
63.00	0	1
79.00	0	1
100.00	0	1

Table VI-M-3.— Particulate matter concentrations at various distances downwind for typical cases No. 3 and No. 4

Distance downwind X(km)	Concentration (χ)		
	Backing fire	Heading fire	
		CL phase	NCL phase
	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
0.10	454	5,179	10,132
.13	370	4,196	8,208
.16	303	3,401	6,649
.20	247	2,757	5,386
.25	204	2,237	4,363
.32	169	1,818	3,535
.40	140	1,480	2,864
.50	117	1,208	2,319
.63	98	987	1,873
.79	82	801	1,497
1.00	69	638	1,169
1.30	61	495	883
1.60	51	397	646
2.00	40	329	459
2.50	30	266	319
3.20	22	206	218
4.00	15	153	147
5.00	10	109	98
6.30	7	76	66
7.90	5	52	44
10.00	3	35	29
13.00	2	24	19
16.00	2	16	13
20.00	1	11	8
25.00	1	7	6
32.00	0	6	4
40.00	0	5	4
50.00	0	4	3
63.00	0	3	2
79.00	0	3	2
100.00	0	2	2

Table VI-M-4. — Particulate matter concentrations at various distances downwind for typical cases No. 5 and No. 6

Distance downwind X(km)	Concentration (X)	
	Backing fire	Heading fire in 2-year-old roughs
	$\mu g/m^3$	$\mu g/m^3$
0.10	901	3,302
.13	730	2,675
.16	591	2,167
.20	479	1,756
.25	388	1,422
.32	314	1,152
.40	256	933
.50	206	756
.63	167	612
.79	135	496
1.00	110	402
1.30	90	325
1.60	72	261
2.00	57	206
2.50	45	157
3.20	37	116
4.00	31	83
5.00	25	59
6.30	19	43
7.90	14	32
10.00	10	25
13.00	7	20
16.00	5	15
20.00	3	10
25.00	2	8
32.00	2	7
40.00	1	6
50.00	1	5
63.00	1	4
79.00	1	3
100.00	1	3

Table VI-M-5. — Particulate matter concentrations at various distances downwind for typical cases No. 7 and No. 8

Distance downwind X(km)	Concentration (χ)			
	In winter		In summer	
	CL phase	NCL phase	CL phase	NCL phase
	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
0.10	30,801	48,633	11,527	18,201
.13	24,952	39,397	9,301	14,687
.16	20,213	31,915	7,505	11,850
.20	16,375	25,855	6,056	9,561
.25	13,265	20,944	4,829	7,625
.32	10,746	16,967	3,851	6,080
.40	8,705	13,745	3,070	4,847
.50	7,052	11,135	2,380	3,758
.63	5,712	9,018	1,827	2,885
.79	4,615	7,287	1,373	2,169
1.00	3,692	5,827	1,002	1,581
1.30	2,887	4,559	708	1,115
1.60	2,188	3,455	487	765
2.00	1,604	2,532	334	512
2.50	1,142	1,803	222	338
3.20	794	1,254	155	220
4.00	543	858	119	142
5.00	367	580	92	91
6.30	248	389	69	58
7.90	173	259	49	38
10.00	127	173	34	24
13.00	98	115	24	17
16.00	76	76	21	14
20.00	57	50	18	11
25.00	42	33	15	9
32.00	36	27	12	8
40.00	32	22	10	6
50.00	28	18	8	5
63.00	23	15	7	4
79.00	19	12	6	4
100.00	16	10	5	3

Table VI-M-6. — Fired-line length correction factors

For typical cases with fired-line length of 400 m when Stability Class C and your fired-line length (meters) is:				For typical cases with fired-line length of 500 m when Stability Class C and your fired-line length (meters) is:			
Distance downwind X (km)	800	1600	3200	Distance downwind X(km)	800	1600	3200
0.10	1.0	1.0	1.0	0.10	1.0	1.0	1.0
.13	1.0	1.0	1.0	.13	1.0	1.0	1.0
.16	1.0	1.0	1.0	.16	1.0	1.0	1.0
.20	1.0	1.0	1.0	.20	1.0	1.0	1.0
.25	1.0	1.0	1.0	.25	1.0	1.0	1.0
.32	1.0	1.0	1.0	.32	1.0	1.0	1.0
.40	1.0	1.0	1.0	.40	1.0	1.0	1.0
.50	1.0	1.0	1.0	.50	1.0	1.0	1.0
.63	1.0	1.0	1.0	.63	1.0	1.0	1.0
.79	1.0	1.0	1.0	.79	1.0	1.0	1.0
1.0	1.1	1.1	1.1	1.0	1.0	1.0	1.0
1.3	1.1	1.1	1.1	1.3	1.1	1.1	1.1
1.6	1.2	1.3	1.3	1.6	1.1	1.1	1.1
2.0	1.4	1.4	1.4	2.0	1.2	1.2	1.2
2.5	1.5	1.7	1.7	2.5	1.3	1.4	1.4
3.2	1.6	2.0	2.0	3.2	1.4	1.6	1.6
4.0	1.7	2.3	2.4	4.0	1.4	1.9	2.0
5.0	1.8	2.7	2.9	5.0	1.5	2.2	2.3
6.3	1.9	3.0	3.5	6.3	1.5	2.4	2.8
7.9	1.9	3.3	4.2	7.9	1.5	2.6	3.4
10.0	1.9	3.5	4.9	10.0	1.6	2.8	4.0
13.0	2.0	3.6	5.6	13.0	1.6	2.9	4.5
16.0	2.0	3.8	6.3	16.0	1.6	3.0	5.0
20.0	2.0	3.8	6.7	20.0	1.6	3.1	5.4
25.0	2.0	3.9	7.1	25.0	1.6	3.1	5.7
32.0	2.0	3.9	7.4	32.0	1.6	3.1	5.9
40.0	2.0	3.9	7.6	40.0	1.6	3.2	6.1
50.0	2.0	4.0	7.7	50.0	1.6	3.2	6.2
63.0	2.0	4.0	7.8	63.0	1.6	3.2	6.2
79.0	2.0	4.0	7.9	79.0	1.6	3.2	6.3
100.0	2.0	4.0	7.9	100.0	1.6	3.2	6.3

continued

Table VI-M-6. — Fired-line length correction factors (Continued)

For typical cases with fired-line length of 800 m when Stability Class C and your fired-line length (meters) is:		
Distance downwind X(km)	1600	3200
0.10	1.0	1.0
.13	1.0	1.0
.16	1.0	1.0
.20	1.0	1.0
.25	1.0	1.0
.32	1.0	1.0
.40	1.0	1.0
.50	1.0	1.0
.63	1.0	1.0
.79	1.0	1.0
1.0	1.0	1.0
1.3	1.0	1.0
1.6	1.0	1.0
2.0	1.0	1.0
2.5	1.1	1.1
3.2	1.2	1.2
4.0	1.3	1.4
5.0	1.5	1.6
6.3	1.6	1.9
7.9	1.7	2.2
10.0	1.8	2.5
13.0	1.9	2.9
16.0	1.9	3.2
20.0	1.9	3.4
25.0	2.0	3.6
32.0	2.0	3.7
40.0	2.0	3.8
50.0	2.0	3.9
63.0	2.0	3.9
79.0	2.0	3.9
100.0	2.0	4.0

For typical cases with fired-line length of 500 m when Stability Class B and your fired-line length (meters) is:			
Distance downwind X(km)	800	1600	3200
0.10	1.0	1.0	1.0
.13	1.0	1.0	1.0
.16	1.0	1.0	1.0
.20	1.0	1.0	1.0
.25	1.0	1.0	1.0
.32	1.0	1.0	1.0
.40	1.0	1.0	1.0
.50	1.0	1.0	1.0
.63	1.0	1.0	1.0
.79	1.0	1.0	1.0
1.0	1.1	1.1	1.1
1.3	1.2	1.2	1.2
1.6	1.3	1.4	1.4
2.0	1.4	1.6	1.6
2.5	1.4	1.9	1.9
3.2	1.5	2.1	2.2
4.0	1.5	2.4	2.7
5.0	1.5	2.6	3.3
6.3	1.6	2.8	3.8
7.9	1.6	2.9	4.4
10.0	1.6	3.0	4.9
13.0	1.6	3.1	5.3
16.0	1.6	3.1	5.6
20.0	1.6	3.1	5.9
25.0	1.6	3.2	6.0
32.0	1.6	3.2	6.1
40.0	1.6	3.2	6.2
50.0	1.6	3.2	6.3
63.0	1.6	3.2	6.3
79.0	1.6	3.2	6.3
100.0	1.6	3.2	6.4

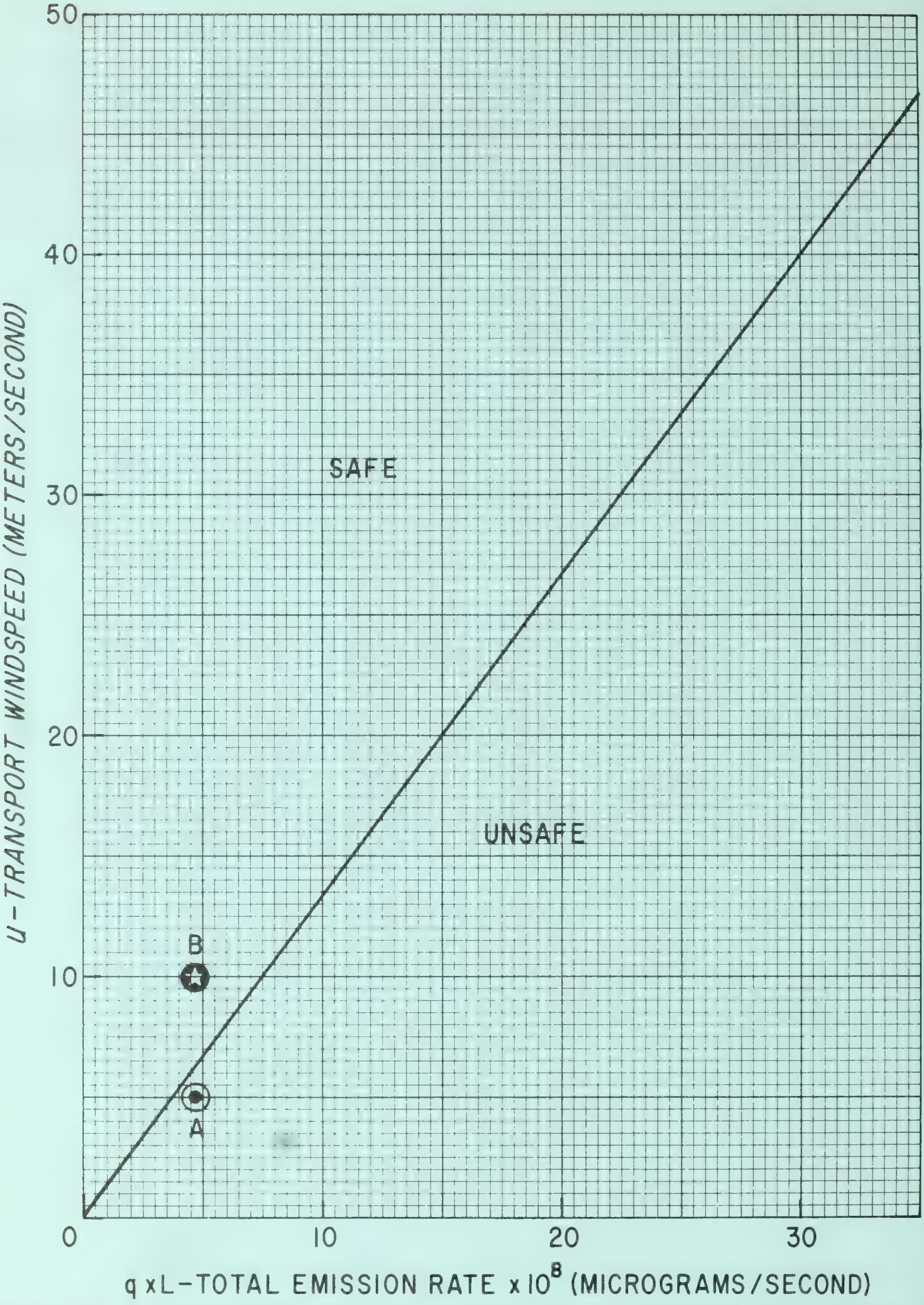


Figure VI-M-1. — Plot of total emission rate (qL) versus transport windspeed (u); ($\frac{qL}{u} = 7.5 \times 10^8$ µg/m^2-sec). To help determine if a fire might deliver 150 micrograms of particulate matter per cubic meter of air to a location 60 or more miles downwind, locate the intersection of your total emission rate (emission rate (ER) x fired-line length (L) with your transport windspeed. For example, a fire with an ER of 1,200,000 µg/m-sec and a 400 m line has a total ER of 480,000,000 µg/sec (i.e., 4.8 x 10^8 µg/sec). Such a fire is unsafe if the transport windspeed is 5 m/sec, but safe if it is 10 m/sec. (See example plotted as A and B, respectively.)

LITERATURE CITED

Blackmarr, W. H.

1971. Equilibrium moisture content of common fine fuels found in southeastern forests. USDA For. Serv. Res. Pap. SE-74, 8 p. Southeast. For. Exp. Stn., Asheville, N.C.

Deeming, John E., James W. Lancaster, Michael A. Fosberg, and others

1972. National fire-danger rating system. USDA For. Serv. Res. Pap. RM-84, 165 p. Rocky Mt. For. & Range Exp. Stn., Fort Collins, Colo.

Hough, Walter A., and Frank A. Albini

In press. Predicting fire behavior in palmetto-gallberry fuel complexes. USDA For. Serv. Res. Pap. Southeast. For. Exp. Stn., Asheville, N.C.

McNab, W. Henry, and M. Boyd Edwards, Jr.

1976. Estimating forest fuel buildup. For. Farmer 35(5):6-7.

Metz, Louis J.

1958. Moisture held in pine litter. J. For. 56(1):36.

Rothermel, Richard C.

1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Res. Pap. INT-115, 40 p. Intermountain For. & Range Exp. Stn., Ogden, Utah.

GLOSSARY

Advancing-front combustion stage. — The period of combustion when a fire is spreading, usually accompanied by flaming combustion that releases heat that sustains the convection column.

Aerosol. — See **Particulate matter.**

Age of rough. — Time in years since the forest fuel was last reduced.

Ambient air. — Literally, the air moving around us; the air of the surrounding environment.

Available fuel. — The portion of the total combustible woody material that fire will consume under given conditions.

Backing fire. — A fire spreading against the wind. Flames tilt away from direction of spread.

Basal area. — The area of the cross section of a tree stem near its base, generally at breast height and inclusive of bark.

Bound water. — Bound moisture. Moisture that is intimately associated with the finer wood elements of the cell wall by molecular sorption.

Breast height. — On standing trees, a standard height (4-1/2 feet) from ground level for recording diameter, girth, or basal area.

Broadcast burn. — The burning of forest residue scattered over an area.

Char. — Charcoal. The residue from the destructive distillation of wood or animal matter with exclusion of air; contains carbon and inorganic matter.

Clearcutting. — Strictly, the *removal* of the entire standing crop.

Climax. — The culminating stage in plant succession for a given environment, the vegetation being conceived or having reached a highly stable condition.

Coagulation. — A separation or precipitation from a dispersed state of suspended particles resulting from their growth.

Combustion. — The burning or rapid oxidation of the pyrolysate vapors escaping from the surface of the fuel.

Condensation. — (1) The linking together of two or more molecules, resulting in the formation of long-chain compounds. (2) The process of forming a liquid from its vapor.

Convection column. — That portion of a smoke plume sharply defined by the buoyant forces of heated air and effluents.

Convective-lift fire phase. — The phase of a fire when most of the emissions are entrained into a definite convection column.

Cord. — A unit of gross volume measurement for stacked round or cleft wood; i.e., based on external dimensions. A standard cord contains 128 stacked cubic feet and generally implies a stack of 4 x 4 feet vertical cross section x 8 feet long, with a small percent extra in height to allow for settlement.

Crop tree. — Any tree forming, or selected to form, a component of the final crop.

Decomposition. — The more or less permanent breaking down of a molecule into simpler molecules or atoms.

Denitrification. — Reducing nitrates to nitrites, nitrous oxide, or nitrogen under anaerobic conditions.

d.b.h. — Diameter at breast height (4-1/2 feet above ground level).

Diffusion. — In meteorology, the exchange of fluid parcels (and hence the transport of conservative properties) between regions in space, in the apparently random motions of a scale too small to be treated by the equations of motion.

Dispersion. — In air pollution terminology, loosely applied to the removal (by whatever means) of pollutants from the atmosphere over a given area; or the distribution of a given quantity of pollutant throughout an increasing volume of atmosphere.

Eddy. — Any circulation drawing its energy from a flow of much larger scale, and brought about by pressure irregularities as in the lee of a solid obstacle.

Effluent. — The mixture of substances, gases and liquids, and suspended matter, discharged into the atmosphere (or ground, river, ocean) as the result of a given process.

Emission. — Pollutants released to the atmosphere from any combustion process. Sometimes used synonymously with effluent, but it is more applicable to atmospheric discharges.

Emission factor. — The quantity of pollutant released to the atmosphere per unit weight of dry fuel consumed during combustion (pounds per ton).

Emission rate. — The quantity of pollutant released to the atmosphere per unit of time per unit length of fire front.

Fermentation layer. — The layer consisting of partly decomposed organic matter. The structure of the plant debris is generally well enough preserved to permit identification of its source.

Fine fuel. — Flash fuels. Fuels; e.g., grass, ferns, leaves, draped (i.e., intercepted when falling) needles, tree moss, and some kinds of light slash, that ignite readily and are consumed rapidly by fire when dry.

Fire behavior. — The manner in which fuel ignites, flame develops, and fire spreads and exhibits other phenomena.

Firing technique. — A method of igniting a wild land area to consume the fuel in a prescribed pattern; e.g., heading or backing fire, spot fire, strip-head fire, and ring fire.

Flaming combustion. — Luminous oxidation of the gases evolved from the decomposition of the fuel.

Flaming phase. — That phase of a fire where the fuel is ignited and consumed by flaming combustion.

Fossil fuels. — Coal, oil, and natural gas; so called because they are the remains of ancient plant and animal life.

Free water. — Free moisture. In wood, moisture contained in the cell cavities and intercellular spaces and held by capillary forces only.

Fuel loading. — The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area. This may be available fuel or total fuel and is usually dry weight.

Fuel type. — An identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics, that will cause a predictable rate of fire spread or difficulty of control, under specified weather conditions.

Glowing phase. — That phase of a fire where the char left from the flaming phase is consumed by solid oxidation.

Heading fire. — A fire spreading with the wind. Flames tilt in the direction of spread.

Heat release rate to the atmosphere. — The amount of heat released to the atmosphere from the advancing-front combustion stage of a fire per unit of time.

Heat yield. — To a very close approximation, the quantity of heat per pound of fuel burned that passes through a cross section of the convection column above a fire that is burning in a neutrally stable atmosphere.

Herbaceous. — Soft and green, containing little woody tissue.

Hydrocarbons. — A general term for organic compounds that contain only carbon and hydrogen in the molecule. They are divided into saturated and unsaturated hydrocarbons, aliphatic (paraffin or fatty), and aromatic (benzene) hydrocarbons.

Humus. — (1) A general term for the more or less decomposed (plant and animal) residues in the soil; litter, therefore, being excluded. (2) More specifically, the more or less stable fraction from the decomposed soil organic material, generally amorphous, colloidal, and dark colored.

Inversion. — Temperature inversion. A layer in which temperature increases with altitude.

Litter. — The uppermost layer, the L-layer, or organic debris on a forest floor; i.e., essentially the freshly fallen or only slightly decomposed vegetable material—mainly foliate (leaf litter)—but also bark fragments, twigs, flowers, fruits, etc.

Micron. — One millionth of a meter, a micrometer.

Mixing. — A random exchange of fluid parcels on any scale from the molecular to the largest eddy.

Mixing height. — The height to which relatively vigorous mixing occurs (meters).

Model. — A mathematical or physical system, obeying certain specified conditions, whose behavior is used to understand a physical, biological, or social system to which it is analogous in some way.

Moisture content. — The amount of water present in a material; e.g., wood or soil, generally expressed as a percent of the material's ovendry weight.

National Fire-Danger Rating System. — The method currently used by the USDA Forest Service and other Federal, State, and county agencies to uniformly describe the cumulative effects of weather on wildfire behavior.

Naval stores. — A term of historical pedigree, still applied to the products of the United States resin industry, nowadays particularly to turpentine and resin, but also to pine tars and pitch.

No-convective-lift fire phase. — The phase of a fire when most emissions are not entrained into a definite convective column.

Nucleate. — To form into or around a nucleus, as in the formation of particulate matter.

Organic soil. — Any soil or soil horizon consisting chiefly of, or containing at least 30 percent of organic matter; examples are peat soil and muck soil.

Ovendry. — Of wood dried to constant weight in a ventilated oven at a temperature above the boiling point of water, generally 103 ± °C.

Overstory. — That portion of the trees, in a forest of more than one story, forming the upper or uppermost canopy layer; e.g., frequent emergents in multi-storied tropical forests or, in a two-storied forest, seed bearers over regeneration and standards over coppice.

Particulate matter. — Any liquid or solid particles suspended in or falling through the atmosphere.

Total suspended particulate matter (TSP) is that portion of the total particulate matter that, because of its size (below 5 to 10 microns in diameter), is transported long distances in the atmosphere and has the greatest potential for environmental impact. Respirable suspended particulate matter (RSP) is that portion of the total particulate matter that, because of its size (below 2 to 3 microns in diameter), has an especially long residence time in the atmosphere and penetrates deeply into the lungs. Aerosol is used interchangeably for the smaller airborne particulate matter by many authorities. However, aerosols are more precisely defined as particles in a gaseous medium.

Particulate mass concentration. — The amount of particulate matter per unit volume of air ($\mu g/m^3$).

Perturbation. — Any departure introduced into an assumed steady state of a system.

Photochemical process. — The chemical changes brought about by the radiant energy of the sun acting upon various polluting substances. The products are known as photochemical smog.

Photosynthesis. — The building up of organic compounds, particularly carbohydrates, in green cells, from CO_2 in the presence of H_2O and light, the energy of the latter being transformed by chlorophyll and enzymes.

Physiological. — Relating to the functions of plant or animal as a living organism.

Plume. — The segment of the atmosphere occupied by any of the emissions from a single source. A convection column, if one exists, forms a specific part of the plume.

Point source. — See **Source.**

Pollutant. — With respect to the atmosphere, any substance within it that is foreign to the *natural* atmosphere or that exceeds its *natural* concentrations in the atmosphere. The universal connotation is that a pollutant is potentially deleterious.

Polymer. — A complex molecule formed from the combination of several molecules and having the same empirical formula as the simple ones.

Pre-ignition phase. — That phase of a fire when the fuel is heated to ignition temperature.

Prescribed burning. — Controlled application of fire to wild land fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc., as allows the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain planned objectives of silviculture, wildlife habitat management, grazing, fire hazard reduction, etc.

Pyrolysis. — The thermal or chemical decomposition of fuel at an elevated temperature.

Rate of spread. — The amount that a fire extends its horizontal dimensions within a unit of time. This can be expressed as forward rate of spread of the advancing fire front, area rate of spread, or perimeter rate of spread.

Residual combustion stage. — The smoldering zone behind the zone of an advancing fire front.

Respirable suspended particulate matter (RSP). — See Particulate matter.

Rough. — An accumulation of living or dead material that is susceptible to burning.

Smoke management. — Conducting a prescribed fire under fuel moisture and meteorological conditions, and with firing techniques that keep the smoke's impact on the environment within acceptable limits.

Smoldering phase. — The combined processes of dehydration, pyrolysis, solid oxidation, and scattered flaming often occurring after the flaming phase of a fire. Often characterized by emissions of large amounts of smoke.

Soluble. — That can be dissolved; capable of passing into solution, as sugar is soluble in water.

Sorption. — The uptake and retention of one substance (the sorbate) at the surface (adsorption) or in the interior (absorption) of another (the sorbent).

Source. — A point, line, area, or volume at which mass or energy is added to a system, either instantaneously or continuously. Conversely, at a *sink,* mass or energy is removed. Examples of sources in the context of air pollution are as follows: a smoke stack is a *point source;* a freeway or aircraft trajectory is a *line source.*

Surface fuel. — The loose surface litter on the forest floor, normally consisting of fallen leaves or needles, twigs, bark, cones, and small branches that have not yet decayed sufficiently to lose their identity. Also grasses, shrubs less than 4 feet in height, heavier branchwood, down logs, stumps, seedlings, and forbs interspersed with or partially replacing the litter.

Synergism. — The cooperative action of separate substances which, together, have greater total effect than the sum of their individual effects.

Target. — Any place at which adverse effects of smoke concentrations may be experienced.

Temperate zone. — Either of two zones of the Earth between the Tropics and the Polar circles.

Thermal energy. — Heat energy.

Total fuel. — The total combustible woody material.

Total suspended particulate matter (TSP). — See **Particulate matter.**

Toxic. — Relating to a harmful effect by a poisonous substance on the human body by physical contact, ingestion, or inhalation.

Transport windspeed. — A measure of the average rate of the horizontal transport of air within the mixing layer (meters per second).

Turbulence. — A complex spectrum of fluctuating, disordered motion superimposed on the mean flow of a liquid or gas.

Understory. — Any plants growing under the canopy formed by others—more particularly—herbaceous and shrub vegetation under a brushwood or tree canopy.

METRIC CONVERSION AND PREFIX TABLE

Metric Conversion

From	Symbol	To	Symbol	Multiply by
		Length		
Inches	in	Centimeters	cm	2.54
Centimeters	cm	Inches	in	0.3937
Feet	ft	Meters	m	0.3048
Meters	m	Feet	ft	3.281
Miles	mile	Kilometers	km	1.609
Kilometers	km	Miles	mile	0.6214
		Area		
Acres	acre	Square meters	m^2	4047
Square meters	m^2	Acres	acre	0.00025
Acres	acre	Hectares	ha	0.4047
Hectares	ha	Acres	acre	2.471
		Volume		
Cubic inches	in^3	Cubic centimeters	cm^3	16.39
Cubic centimeters	cm^3	Cubic inches	in^3	0.061
Cubic feet	ft^3	Cubic meters	m^3	0.0283
Cubic meters	m^3	Cubic feet	ft^3	35.31
		Mass		
Pounds	lbs	Grams	g	453.6
Grams	g	Pounds	lbs	0.0022
Pounds	lbs	Kilograms	kg	0.4536
Kilograms	kg	Pounds	lbs	2.205
Short tons	sh. ton	Metric tons	m. ton	0.9072
Metric tons	m. ton	Short tons	sh. ton	1.102
		Speed		
Feet/minute	ft/min	Meters/minute	m/min	0.3048
Meters/minute	m/min	Feet/minute	ft/min	3.281
Miles/hour	mph	Kilometers/hour	km/hr	1.609
Kilometers/hour	km/hr	Miles/hour	mph	0.6214
		Temperature		
Fahrenheit	°F	Celsius	°C	5/9 after subtracting 32
Celsius	°C	Fahrenheit	°F	9/5 then add 32
		Energy		
British thermal units	Btu	Calories	cal	252.0
Calories	cal	British thermal units	Btu	0.004

Multiple	Prefix Prefix	Symbol
1,000,000,000 = 10^9	giga	G
1,000,000 = 10^6	mega	M
1,000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deka	da
1 = 10^0		
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n

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1976. Southern forestry smoke management guidebook. USDA For. Serv. Gen. Tech. Rep. SE-10, 140 p. Southeast. For. Exp. Stn., Asheville, N.C.

A system for predicting and modifying smoke concentrations from prescription fires is introduced. While limited to particulate matter and the more typical southern fuels, the system is for both simple and complex applications. Forestry smoke constituents, variables affecting smoke production and dispersion, and new methods for estimating available fuel are presented.

Keywords: Air quality, pollution, prescribed burning, smoke management, particulate matter, smoke concentrations, emission factors, components of forestry smoke, fuel loading.

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